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A PRELIMINARY ASSESSMENT OF THE GEOLOGY AND MINERAL RESOURCES OF THE PLASTER ROCK BASIN AND ADJACENT AREA, VICTORIA COUNTY, NEW BRUNSWICK

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A Preliminary Assessment of the Geology and Mineral Resources of the Plaster Rock Basin and Adjacent Area, Victoria County, New Brunswick

This report has been prepared by:

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Department of Natural Resources and Energy
Province of New Brunswick

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Minister of State for Mines and Energy

April 1992

New Nouveau
Brunswick

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D.V. Venugopal and T.C. Webb

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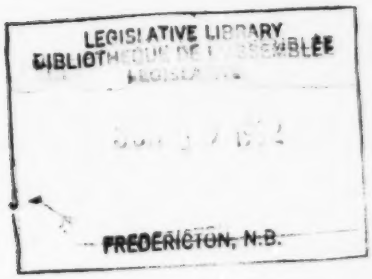

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ABSTRACT

The physiographic and geologic setting of the Plaster Rock Basin and adjacent areas in Victoria County, New Brunswick, were used to identify and assess potential rock and mineral resources in the region.

Notable rock and mineral resources within the study area include: limestone, gypsum, and aggregate (granular and bedrock). Several base metal occurrences and two specific exploration targets have also been identified in the region.

In general, limestone of the Plaster Rock Basin seldom contains more than 45-50% CaO. The thickness and lateral extent of higher-grade deposits is variable. Pit-run material would be considered of substandard quality for most raw material industrial specifications.

The quality and extent of gypsum in the region is also variable. With few exceptions, the Plaster Rock gypsiferous deposits fall short of fulfilling basic raw material requirements for most popular gypsum applications (i.e., wallboard manufacture). However, the resource may offer some potential for agriculture if deposits identified to date can be reasonably upgraded to appropriate standards or higher-quality deposits can be located. An increase in consumption of agricultural gypsum has been reported in the large potato-producing region of northwestern New Brunswick and northern Maine.

The Plaster Rock region seems to have adequate supplies of aggregate but is deficient in high-quality pit-run granular material. The potential for high-specification bedrock aggregate is good. The utilization of these resources is transportation-sensitive, depending on their distance from major construction projects.

Occurrences of base metals in the Plaster Rock region are restricted to rocks of Lower Devonian age, several kilometres to the east of the village. Recent exploration activity would suggest that these rocks have the potential for hosting volcanogenic massive sulphide or epithermal mineral deposits.

RÉSUMÉ

Le cadre physiographique et géologique du bassin de Plaster Rock et des régions adjacentes du comté de Victoria, au Nouveau-Brunswick, a servi à définir et à évaluer les ressources rocheuses et minérales possibles de la région.

Les ressources rocheuses et minérales notables de la zone étudiée comprennent du calcaire, du gypse et des agrégats (granulaires et rocheux). Plusieurs venues de métaux communs et deux objectifs d'exploration précis ont également été définis dans la région en question.

De manière générale, le calcaire du bassin de Plaster Rock renferme rarement plus de 45 à 50 p. 100 de CaO. L'épaisseur et la dimension transversale des gisements à plus forte teneur varient. Le matériel tout-venant est jugé de qualité inférieure du point de vue de la plupart des spécifications industrielles relatives aux matières premières.

La qualité et l'étendue du gypse de la région varient également. À quelques exceptions près, les gisements gypsifères de Plaster Rock ne répondent pas aux exigences de base visant les matières premières pour presque toutes les utilisations populaires du gypse, notamment la fabrication des panneaux muraux. La ressource est toutefois susceptible d'offrir un certain potentiel sur le plan agricole, si les gîtes reconnus à ce jour pouvaient être raisonnablement améliorés pour satisfaire à des normes adéquates, ou si des gisements de qualité supérieure pouvaient être localisés. Les régions de grande production de pommes de terre du nord-est du Nouveau-Brunswick et du nord du Maine ont enregistré une consommation accrue de gypse agricole.

La région de Plaster Rock semble posséder des réserves adéquates d'agrégats, mais elle souffre d'une carence de granulats tout-venant de haute qualité. Cependant, son potentiel d'agrégats rocheux de qualité supérieure demeure intéressant. L'utilisation de ces ressources est fragile au transport, selon la distance qui les sépare des grands projets de construction.

Les venues de métaux communs de la région de Plaster Rock se limitent à des roches du Dévonien inférieur situées à plusieurs kilomètres à l'est du village. Des activités d'exploration récentes laissent supposer que ces roches contiendraient des gisements de sulfures massifs d'origine volcanique ou des gisements minéraux épithermaux.

A PRELIMINARY ASSESSMENT OF THE GEOLOGY AND MINERAL RESOURCES OF THE PLASTER ROCK BASIN AND ADJACENT AREA, VICTORIA COUNTY, NEW BRUNSWICK

INTRODUCTION

This report encompasses a review and assessment of the geology and mineral resources of the Plaster Rock Basin and adjacent area in Victoria County, New Brunswick. The region under investigation extends 30 km east and 16 km west of the Village of Plaster Rock. The dispersed communities of Gladwyn and Riley Brook mark the southern and northern boundary, respectively, of the study area (Figure 1).

Information for this undertaking has been compiled and synthesized from various published and unpublished reports, and mineral exploration reports of work (assessment reports) that have been submitted to the Mineral Resources Division of the New Brunswick Department of Natural Resources and Energy. Additional data were acquired through field investigations carried out during the summer and fall of 1990, followed up by laboratory studies. As a result, this report provides new qualitative information pertaining to the region's gypsum and limestone deposits and its bedrock aggregate resources.

The report is intended as a general guide to the physiographic and geologic setting of the Plaster Rock Basin. Background information is provided on the basin's stratigraphy, structure, and surficial geology, as well as an inventory and preliminary assessment of the area's mineral resources. The mineral inventory contains details of the distribution, quality, quantity, and potential significance of the region's more notable mineral resources.

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The report and maps have benefited greatly from discussions and constructive reviews by Reginald A. Wilson, Allan A. Seaman, and Barbara M.W. Carroll. Mitch O'Donnell diligently performed engineering tests on bedrock aggregate samples. Kim Stewart and Diane Blair typed parts of the report. Terry Leonard and Gerry Johnson drafted maps and figures. Thanks to all for a job well done!

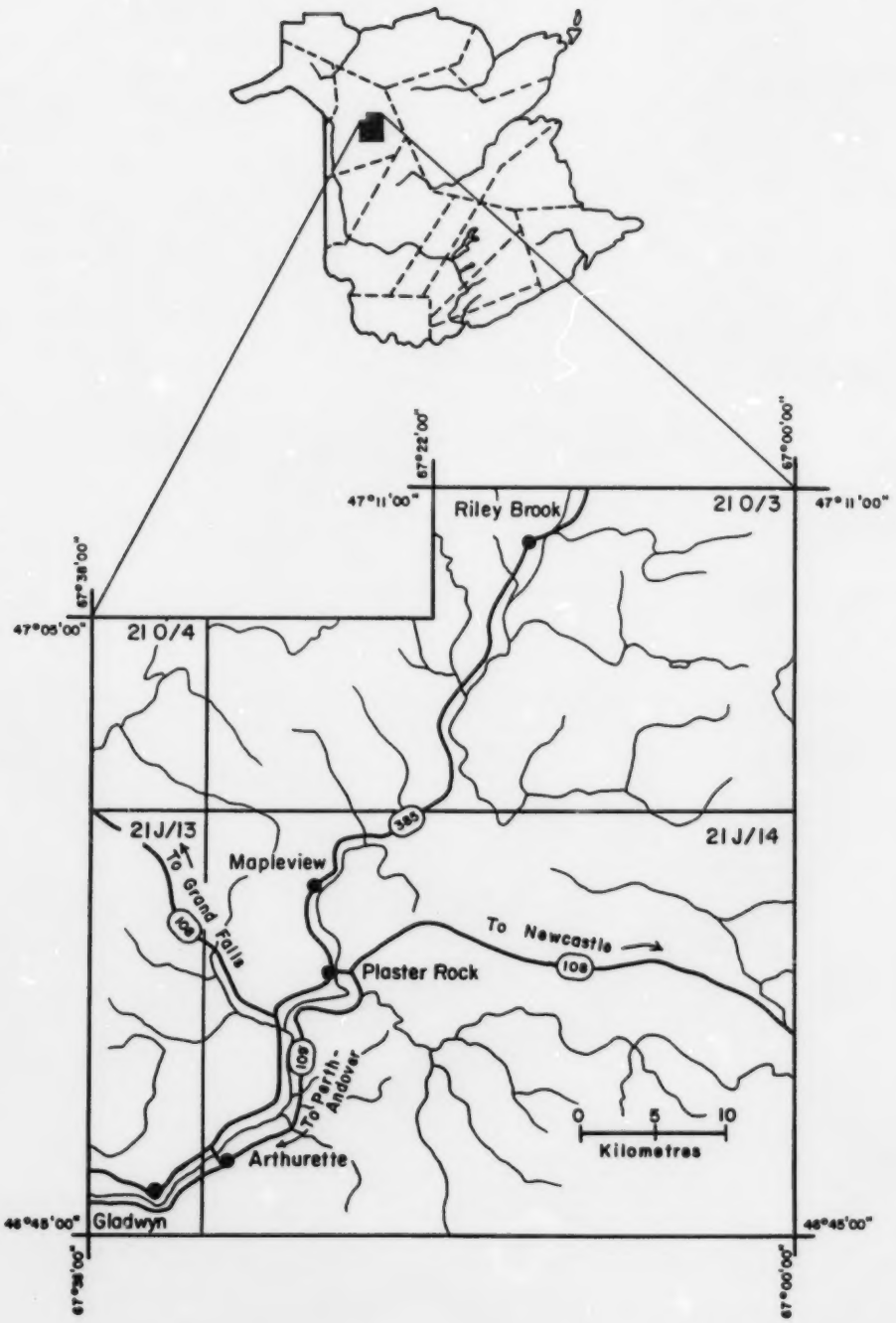


Figure 1. Location of the Plaster Rock Basin, Victoria County, New Brunswick.

PREVIOUS WORK

The Plaster Rock Basin is probably best known for its indigenous deposits of limestone and gypsum. These deposits have been explored for periodically since the mid-nineteenth century. Among the earliest descriptions of these rocks are those given by Hind (1865), Robb (1870), Bailey (1864, 1885, 1886, 1899), Bailey and McInnes (1887), and Goudge (1934).

Sund studied the origin of gypsum deposits in New Brunswick in 1958. As part of this study, he discussed the genesis of gypsum in the Plaster Rock Basin. Hamilton (1965), Hamilton and Barnett (1970), Webb and Kingston (1975), and Webb (in press) have also conducted geological investigations pertaining to limestone–gypsum deposits in the study area.

One of the first geological maps of the Plaster Rock area was prepared by Rose (1936). More recently, Skinner (1971 1975, 1982) carried out several regional mapping projects primarily over the Devonian rocks east of the village. St. Peter (1977, 1978, 1979, 1981) and Irrinki (1977a, 1977b, 1977c) have mapped parts of the basin and adjacent areas. Davies (1979) and Fyffe (1982a, 1982b, 1982c) have produced geological compilation maps of the area based on previous work.

Fyffe and Pronk (1985) investigated the bedrock and surficial geology and till geochemistry northeast of Plaster Rock. A detailed description of the base metal deposit near Costigan Mountain was included in their report.

Thibault (1980) and Lavergne and Hunter (1982) have reported on the granular aggregate resources of the region. The distribution and classification of these deposits are summarized in the "Atlas of Granular Aggregate Resources, New Brunswick" (New Brunswick Department of Natural Resources and Energy 1987). Various aspects of the region's Quaternary geology have been described by Rampton and Paradis (1981), Rampton *et al.*, (1984) and Rappol (1986a 1986b, 1988).

Wilson (1988, 1990) carried out detailed geological mapping and lithogeochemical studies in the region. The study included a reinterpretation of the stratigraphy and structure of Lower Devonian age rocks in the area west and north of the Plaster Rock Basin. This comprehensive data base will be a useful guide in identifying areas or zones favourable for metallic mineral deposits.

Although the region has been explored for various minerals since the mid-nineteenth century, detailed documentation in mineral exploration reports of work (assessment reports) began in 1954 (Plates 92-53A and -53B, 92-54A and -54B, 92-55A and -55B).

PHYSIOGRAPHY

The Plaster Rock Basin comprises three physiographic domains that form an integral part of the extensive Chaleur Bay Uplands (Bostock 1970). Each domain is characterized by a distinct landform; from northwest to southeast they are: (1) a northeast-trending zone underlain by Ordovician–Silurian argillaceous and calcareous metasedimentary rocks covered by a thick blanket of glacial deposits that display a gentle rolling topography; (2) a region of low relief underlain by horizontal to shallow-dipping Carboniferous strata; and (3) a narrow zone of uplands underlain by Silurian–Devonian volcanic, sedimentary, and intrusive rocks. The volcanic rocks and their intrusive equivalents form resistant subcircular to circular plugs, elongate hills, and ridges. The topography in areas underlain by these rocks is variable with many high peaks located east and north of the Plaster Rock Basin.

Silurian–Devonian rocks are moderately to well exposed in the areas northwest, southeast, and northeast of the Plaster Rock Basin. Exposures of Carboniferous strata underlying most of the basin are limited to its western margins.

The study area is drained by deeply incised streams. In the area to the east and north of Plaster Rock, the drainage pattern is orthogonal, whereas a dendritic pattern is more typical south of the village.

REGIONAL GEOLOGIC SETTING

Northwestern New Brunswick is underlain by polydeformed and metamorphosed rocks of the Miramichi Terrane, in fault contact with the Late Ordovician Matapédia Cover Sequence (Fyffe and Fricker, 1987). In New Brunswick, Matapédia rocks range in age from Silurian to Ordovician. They have been divided into three tectonostratigraphic zones (Rodgers 1970; Davies 1979; Ruitenberg *et al.* 1977): the Chaleur Zone, the Tobique Zone, and the Aroostook-Matapédia Zone (Figure 2). Each zone is characterized by rocks of similar age, type, tectonic history, and mineral-bearing potential. For the most part, the Plaster Rock Basin and the adjoining areas lie within the Tobique and the Aroostook-Matapédia zones. The main lithologies and stratigraphic relationships within these zones are summarized in Table 1.

The northeast-trending Aroostook-Matapédia Zone (Malo 1988), extending from eastern Maine to the Gaspé Peninsula in Québec, is underlain by: (1) tightly folded silty argillite and argillaceous sandstone comprising distal turbidite deposits of the Grog Brook Group (St. Peter 1977); and (2) thinly interbedded calcareous shales and argillaceous limestones of the Matapédia Group, which conformably overlie and interfinger with the Grog Brook strata.

The Tobique Zone extends from Woodstock in the southwest to Upsalquitch Forks in the northeast. It is juxtaposed against the Aroostook–Matapédia Zone by the Rocky

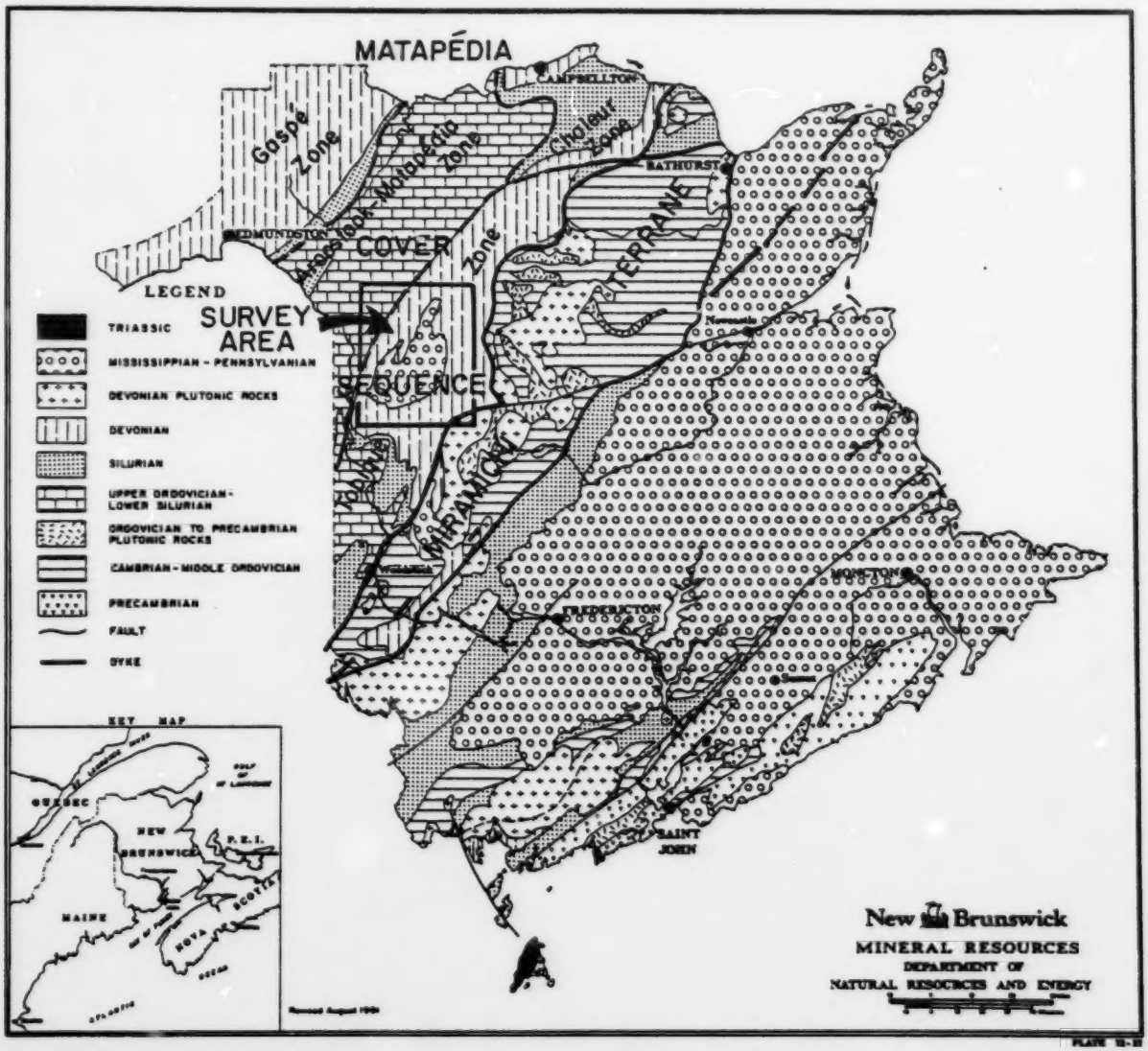


Figure 2. Map showing the Plaster Rock Basin and the tectonostratigraphic zones of northwestern New Brunswick.

TABLE 1. Table of Formations, Plaster Rock Basin and Adjacent Area, Victoria County, New Brunswick

ERA	PERIOD	GROUP/ FORMATION	MAP UNIT	LITHOLOGY
PALEOZOIC	Pennsylvanian		Ps	Red conglomerate and sandstone
	Mississippian	Plaster Rock Formation	Ms_3	Red and green shale, gypsiferous shale and gypsum
			Ms_2	Red shale, shaly and nodular limestone
		Arthurette Redbeds	Ms_1	Red sandstone, conglomerate; minor red mudstone and buff to grey quartz-pebble conglomerate and sandstone
		Gladwyn Basalt	Mmv	Greyish black, amydaloidal basalt
	UNCONFORMITY			
	Early to Middle Devonian		Dm	Green to grey, fine- to medium-grained diabase gabbro
	Intrusive Contact			
	Lower Devonian	Tobique Group	Dmv	Mostly grey to green, massive to pillowed basalt, amydaloidal basalt, hyaloclastic tuff; with minor diabase (Dm); and intercalated and/or interbedded grey and greyish green sandstone (Ds) and felsic volcanic rocks (Dfv)
			Dfv	Mostly buff to pink and grey aphanitic rhyolite, quartz feldspar porphyry, grey to pink eutaxitic ash-flow tuff and orange to dark grey flow-banded rhyolite; minor mafic volcanic rocks (Dmv) and metasedimentary rocks (Ds)
			Ds	Mostly grey lithic sandstone, quartzose sandstone, siltstone, slate, and polymictic conglomerate; minor mafic volcanic rocks (Dmv) and felsic volcanic rocks (Dfv)
	Silurian	Perham Group	Ss	Grey to green, massive to parallel-laminated calcareous siltstone and sandstone; massive, fine- to medium-grained quartzose sandstone and lithic wacke; minor shale and polymictic conglomerate
	Ordovician and/or Silurian	Matapédia Group	OSs	Dark grey to black, thinly interbedded slate and light grey to black limestone; minor shale and manganiferous and pyritic dark slate
	Fault Contact			
	Ordovician		Of	Pink, fine- to medium-grained, foliated augen granite
			Om	Green, medium-grained schistose gabbro

Brook–Millstream Fault to the north. The Woodstock–Portage Lakes–Serpentine River Fault system marks the zone's southern boundary with the Miramichi Terrane. The Tobique Zone is underlain by Silurian carbonate and siliciclastic sedimentary rocks of the Perham Group (Boucot *et al.* 1964; Roy and Mencher 1976; Fyffe 1982d) and Siluro-Devonian sedimentary and bimodal volcanic and minor intrusive rocks belonging to the Tobique Group (St. Peter 1978, 1979; Fyffe 1982d).

The Siluro-Devonian rocks are unconformably overlain by Mississippian strata in the Plaster Rock Basin. These Mississippian rocks are divided into: the Gladwyn Basalt, the Arthurette Redbeds, and the Plaster Rock Formation (St. Peter 1979). They are overlain by Pennsylvanian conglomerate and sandstone.

STRATIGRAPHY

ORDOVICIAN

Ordovician gabbro and foliated augen granite, restricted to the southeast corner of the study area (Figure 3, Plate 92-49B), are juxtaposed against younger rocks to the northwest along the Catamaran Fault.

Gabbro (Unit Om): A wedge-shaped gabbro body approximately 2 km in length is found about 3 km southwest of Beaver Lake. According to St. Peter (1981), it is a mottled dark green and white, fine- to medium-grained rock displaying a massive subophitic to schistose texture. The rock is composed of plagioclase (45-50%), actinolite (20-30%), hornblende (up to 10%), biotite (up to 10%), quartz (2-5%), sphene (up to 1%), and magnetite (1%). The feldspar is altered to sericite and/or epidote and clinozoisite, whereas amphibole is altered to chlorite. Prehnite occurs in late quartz-chlorite fracture-filled veins.

The gabbro is completely enclosed and intruded locally by an augen granite that contains abundant xenoliths of the gabbro. The gabbro has been interpreted as a roof pendant within the granite (Crouse 1978; Irrinki 1978) that predates the Middle Ordovician (St. Peter 1981).

Augen Granite (Unit Of): Augen granite underlies an area of approximately 10 km^2, south of Right Hand Branch River de Chute and Beaver Lake. The granite is composed of leucocratic (pink) quartzo-feldspathic layers alternating with dark grey, biotite-rich melanocratic layers that vary in width from 1 to 4 mm and contain "augens" (2-10 mm in length) comprising plagioclase and potash feldspar. Feldspar augens typically constitute 5 to 25% of the granite. The main mineral components include quartz (15-30%), plagioclase (10-30%), potash feldspar (25-50%), and mica (3-15%). Minor minerals include chlorite, zircon, apatite, magnetite, hematite, epidote, sphene, and allanite.

Figure 3. General geology of the Plaster Rock Basin and adjacent area, Victoria County, New Brunswick.

LEGEND

PENNSYLVANIAN

Ps — Conglomerate, sandstone

MISSISSIPPIAN

Plaster Rock Formation

Ms_3 — Shale, gypsum

Ms_2 — Shale, limestone

Arthurette Redbeds

Ms_1 — Sandstone, conglomerate, mudstone, and basalt

DEVONIAN

Dsv — Sedimentary and volcanic rocks with their intrusive equivalents

SILURIAN

Perham Group

Ss — Sandstone, conglomerate, and limestone

ORDOVICIAN/SILURIAN

OSs — Slate and limestone

ORDOVICIAN

Of — Granite

Om — Gabbro

Approximate geological boundary

Approximate fault

Plaster Rock Basin

5 0 5 10

KILOMETRES

The granite shows many textural variations, a result of varying degrees of recrystallization. A foliated type displays textures related to partial melting and/or anatectic melting (St. Peter 1981). The age of the foliated augen granite is not known but a date for a similar rock type in the Sevogle River area nearby would suggest it may be Early to Middle Ordovician (Fyffe et al. 1977).

ORDOVICIAN AND SILURIAN

Matapédia Group (Unit OSs): Rocks of the Matapédia Group are restricted to a northeast-trending belt in the northwestern part of the study area (Figure 3, Plates 92-49A and 92-49B). The belt is bounded to the south by the Rocky Brook–Millstream Fault.

In the study area, the Matapédia Group comprises two main lithofacies: a predominantly carbonate facies ("ribbon rock" limestone) referred to as the Carys Mills Formation (St. Peter 1977) that is locally overlain by a less extensive arenaceous facies informally called the New Denmark Argillite (Wilson 1990).

The Carys Mills Formation (Pavlides 1968) is described as a sequence of thin- to medium-bedded, dark grey to black, grey-weathered, calcareous to noncalcareous shale and argillite with a pale grey to bluish grey or black, brown-weathered shaly limestone. Differential weathering of argillaceous and more resistant limy beds produces the ribbon pattern typical of this unit. Individual beds range in thickness from less than 1 cm to 10 cm and locally up to 0.5 m. Beds display interrupted Bouma sequences typical of turbidite deposits (Bouma 1962, St. Peter 1978, and Wilson 1990).

Toward the top of the Matapédia Group, the Carys Mills rocks are interbedded with and overlain by wackes and arenites of the New Denmark Argillite (Wilson 1990). These strata consist of mainly dark grey to black, massive to parallel-laminated argillite, slate, and friable siltstone. Locally, the argillite sequence contains thin beds of dark grey wacke, quartzite, and coarse lithic wacke. In the proximity of fault zones, these beds are highly sheared and boudinaged.

Few fossils have been identified in Mapatédia Group rocks in the study area. However, fossils in similar Matapédia strata in Maine and the Gaspé Peninsula of Québec indicate a Late Ordovician (middle Caradocian to Ashgillian) to Early Silurian (middle Llandoverian) age (Wilson 1990).

SILURIAN

Perham Group (Unit Ss): In the study area, the Perham Group includes the Hazeldean Formation and the Chambord Brook Limestone (Wilson 1990). In this report these units are not described separately.

The Perham Group, located northwest of the village of Plaster Rock (Figure 3, Plate 92-49B), consists of dark grey to greenish grey, massive to parallel-laminated, calcareous and fossiliferous siltstone and sandstone interbedded with quartzose sandstone and lithic wacke (Wilson 1990). Fossils in these rocks are typical of lower Silurian (early Llandovery) assemblages. Locally, lithic wackes and sandstones contain sedimentary and volcanic lithic clasts, accounting for about 20% of the rock. Perham rocks display a variety of sedimentary structures providing evidence of sediment dewatering and loading, and bioturbation. Parallel laminations, minor cross bedding, and associated faunal assemblages are indicative of a neritic shelf environment of deposition (Wilson 1990).

In the Salmon River–Sutherland Brook area, the Perham Group is represented by a fault-bounded wedge of fossiliferous limestone that is hard, reddish brown to pale grey, and shows abundant closely packed fossil fragments (packstone). Fossils include fragmented coral, shelly fauna, crinoid ossicles, and a few trilobites. The faunal assemblage suggests a Middle Silurian (Wenlockian) age (Wilson 1990).

LOWER DEVONIAN

Tobique Group: The Tobique Group occurs extensively throughout the eastern half of the study area (Figure 3). St. Peter (1978) has divided the group into two formations: the Costigan Mountain Formation and the overlying and interfingering Wapske Formation. However, for the purpose of this report, a generalized description has been adopted.

Within the study area, the group is divided into three main lithotypes: mafic volcanics (unit Dmv), felsic volcanics (unit Dfv), and sedimentary rocks (unit Ds). Since these lithotypes are often interbedded and intercalated with one another, the order of description does not imply stratigraphic age relationships.

Sedimentary Rocks (Unit Ds): Sedimentary rocks comprise approximately one third of all Devonian rocks in the study area. These are mainly siltstones and fine-grained sandstones, with minor slate and conglomerate. Sandstone is grey to green, fine- to medium-grained, and is commonly interbedded with siltstone. Beds vary from a few centimetres to more than a metre thick. They are massive locally; however, parallel laminations and wave- or current-ripple cross laminations, are commonly seen in interbedded sandstone–siltstone sequences. Sandstones are typically quartz-rich arenite, but are locally arkosic. The matrix is noncalcareous to moderately calcareous and contains abundant chlorite, sericite, and minor calcite and submicroscopic silicates. Locally, the sandstone and siltstone display yellowish brown limonitic and/or red staining due to oxidation of iron-bearing minerals.

Sandstone and shale often grade into mudstone and/or slate. The slate and mudstone are thin to thick bedded and locally grade into lithic wacke, which is typically dark grey, medium to very coarse grained. Lithic clasts consist mainly of quartz and fine-grained felsic volcanics with lesser amounts of feldspar, feldspar porphyry, amygdaloidal mafic

volcanics, and fine-grained granite (St. Peter 1981). The matrix of the rock contains mostly chlorite with minor amounts of muscovite, calcite, and fine disseminations of opaque mineral(s).

Conglomerate is a minor component of the Devonian sedimentary rocks. It is commonly polymictic and is interbedded with reddish siltstone and sandstone (Wilson 1990). Clasts consist of felsic and mafic volcanic rocks, sedimentary rocks, quartz, and feldspar set in a fine-grained hematite- to limonite-rich matrix.

Felsic Volcanic Rocks (Unit Dfv): Felsic volcanic rocks constitute about 20 to 25% of the Tobique Group. Because of their resistant nature, they tend to form steep ridges and topographic highs. The unit includes quartz-feldspar porphyry, quartz porphyry, ash-flow tuff, flow-banded rhyolite, and minor pyroclastic breccia that are commonly interbedded with minor mafic volcanic and metasedimentary rocks.

Feldspar and quartz-feldspar porphyries and the tuffaceous rocks grade into each other, suggesting that they are temporally and spatially related. The porphyries are reddish pink to purplish grey and display a buff to pink weathered surface. Phenocrysts of quartz and feldspar, 0.5 mm to 6 mm in length, make up 5 to 30% of the rock. Feldspar phenocrysts are most commonly plagioclase of oligoclase to andesine composition. Orthoclase is present locally. At some localities, the phenocrysts form close clusters or aggregates of equant plagioclase giving the rock glomeroporphyritic texture. Flattened spherulites and parallel to sub-parallel alignment of tiny plagioclase laths are among some of the other textural variations in the porphyries. The matrix is composed of cryptocrystalline quartz and feldspar, with minor amounts of chlorite, epidote, calcite, and sphene.

Pyroclastic rocks, including ash-flow, ash fall, and lapilli tuffs, are intercalated with porphyries. They typically show alternating light and dark grey laminations and/or elongate lenses defining an eutaxitic foliation.

Rhyolite flows, occurring mainly along the eastern edge of the study area, constitute a small percentage of the felsic volcanic rocks in the region. They are grey, pink, light green, and reddish orange in colour and display a white to buff and rusty brown weathered surface. Flow laminations, ranging from 1 to 5 mm in width, are delineated by varying amounts of fine-grained hematite, quartz, biotite, chlorite, epidote, and sericite. Locally, the rock also displays spherulitic aggregates with axiolitic texture.

Locally, felsic subvolcanic intrusive rocks cross-cut the felsic volcanic rocks. These intrusions occur as small remnant plugs or volcanic necks and vary in composition from rhyolite to dacite to monzonite.

Mafic Volcanic Rocks (Unit Dmv): Mafic volcanic rocks, comprising basalt, basaltic tuff, and diabase, constitute about 20 to 25% of Lower Devonian strata, and occur near the eastern margin of the Plaster Rock Basin. The basalts are greyish green to dark green and display greyish brown to brown weathered surfaces. They form massive to amygdaloidal

flows and in some areas display pillow structures. Amygdules are generally filled with quartz, chlorite, and/or calcite. A typical flow is composed of clinopyroxene, plagioclase and variable amounts of epidote, sphene, chlorite, carbonate, and opaque minerals, depending on the intensity of alteration. The plagioclase is of andesine or labradorite composition.

Flows are intercalated with dark grey or green tuff consisting of corroded plagioclase, fragments of amygdaloidal basalt, and accidental lapilli of siltstone, sandstone, and felsic volcanic material. The matrix is an aggregate of chlorite, feldspar, calcite, epidote, sphene, and minor quartz.

A mafic fragmental rock, occurring mostly in the eastern part of the study area, was referred to as "peperite" by Skinner (1982) and described as a basalt-siltstone-slate melange with an agglomeratic appearance. The breccia is composed of variable amounts of mafic volcanic and siltstone fragments in a mafic volcanic or argillaceous matrix. In breccia that contains a silty matrix, mafic volcanic fragments are surrounded by palagonite. The mafic volcanic fragment(s) within the palagonite layer contain variable amounts of plagioclase laths, minor epidote, and amygdules of chlorite and calcite in a matrix of chlorite, calcite, and palagonite. Hyaloclastic textures are developed in sedimentary and mafic volcanic rocks, a result of decrepitation and thermal shattering of a rapidly quenched basaltic magma flowing into water-saturated sediment (MacDonald 1972; Williams and McBirney 1979). Palagonite and chlorite are formed from the devitrification of congealed and cooled glass fragments.

Age and Depositional Synthesis of the Tobique Group: The sedimentary rocks of the Tobique Group contain faunal assemblages consisting of mainly brachiopods and, to a lesser extent, bryozoans, crinoids, trilobites, and rare cephalopods. These are diagnostic of an early Devonian (early Helderbergian) age (St. Peter 1978, 1979, 1981; Skinner 1982; Wilson 1990).

Textural features in mafic volcanic rocks, sedimentary structures, and faunal assemblages suggest a shallow marine environment of deposition for the Tobique Group. For the most part, felsic volcanic rocks are considered to be terrestrial or shallow-water deposits.

Gabbro and Diabase (Unit Dm): Mafic intrusive rocks account for about 10 to 15% of the Devonian igneous rocks. Gabbro and diabase occur as dykes, sills, and subcircular to circular and elongate bodies. These intrusives commonly occur within the Devonian mafic volcanic and sedimentary sequence. Two large bodies of gabbro occur along the eastern and southeastern edge of the Plaster Rock Basin (Plate 92-49B). A pronounced magnetic anomaly (Geological Survey of Canada 1953; Allan Spector and Associates Limited 1980) suggests that the basin is underlain by mafic intrusive rocks.

Gabbro is typically medium grey to dark greyish green and displays a buff to brown weathered surface. Locally, the rock is fine to medium grained and displays a porphyritic texture. Compositionally, it consists of 35 to 80% plagoiclase, 5 to 40% clinopyroxene,

minor quartz, and trace amounts of sphene and opaque minerals (St. Peter 1979). Interstitial masses and/or pseudomorphs, chlorite after clinopyroxene, locally account for about 25% of the bulk mineral composition.

The intrusive nature of the gabbro is evident from diabasic chilled margins that are locally up to several metres wide. Near some of the intrusive margins, gabbroic rocks contain xenoliths of mafic volcanic rock and metasedimentary rocks similar to those of the Tobique Group. In some areas, a transitional contact between gabbroic and volcanic rocks is characterized by variations in grain size and texture. The textures and transitional contacts of the mafic intrusive rocks suggest a shallow intrusive to partly extrusive origin and were probably co-magmatic and nearly coeval.

Mafic dykes, common in the northwestern and northeastern parts of the study area (Plate 92-49A), intrude all pre-Carboniferous rocks. Generally, they are 1.0 to 5.0 m wide and trend northeast. Wilson (1990) reported a 70 m wide dyke north of Foley Brook. The mafic dykes are plagioclase- and/or augite-phyric to diabasic in composition. They are variably altered and display intergranular to ophitic textures (Wilson 1990).

MISSISSIPPIAN

The Mississippian rocks of the Plaster Rock Basin are divided into three formations (St. Peter 1979). From oldest to youngest, they are the Gladwyn Basalt, Arthurette Redbeds, and Plaster Rock Formation. An angular unconformity separates the Gladwyn Basalt and Arthurette Redbeds from the underlying Lower Devonian rocks.

Gladwyn Basalt (Unit Mmv): The Gladwyn Basalt is restricted to the southwestern part of the area, near the village of Gladwyn on the north side of the Tobique River (Figure 3, Plate 92-49B), where it overlies Devonian rocks in the vicinity of Pettingill Lake and south of Piccadilly. It has an estimated thickness of about 30 m (St Peter 1979). The basalt is locally underlain by a thin bed of red lithic arenite.

The basalt is greyish black and fine-grained. Textural variations range from amygdaloidal to porphyritic. Phenocrysts, constituting up to 20% of the rock, consist of 10 to 15% plagioclase and 3 to 5% clinopyroxene. The matrix is composed of fine-grained plagioclase (probably labradorite), clinopyroxene, opaque minerals, chlorite, sphene, apatite, and quartz. Vesicles in the amygdaloidal basalt contain analcime, quartz, and calcite. The basalt is altered, with much of the plagioclase in the matrix and phenocrysts replaced by calcite, chlorite, and quartz. Locally, the basalt displays columnar jointing.

Chemical analysis of two samples (Fyffe and Barr 1986) indicates the basalt is of tholeiitic composition. The age of the basalt is not known precisely. However, a late Tournaisian to early Visean age is suggested because it immediately underlies sedimentary rocks of the Plaster Rock Basin, which are correlated with the mid-Visean Windsor Group (Rose 1936; Sund 1958, and St. Peter 1979).

Arthurette Redbeds (Unit Ms_1): The Arthurette Redbeds are the most extensive sequence of Mississippian age rocks within the Plaster Rock Basin. The unit underlies an area extending from Arthurette in the south to Riley Brook in the north, and from Crombie Settlement in the west to about 5 km east of Longley (Figure 3, Plates 92-49A and 92-49B).

The Arthurette Redbeds conformably overlies the Gladwyn Basalt and unconformably overlies Tobique Group strata. St. Peter (1979) estimates an overall thickness of about 550 m.

As the name suggests, the Arthurette rocks consist of an interbedded sequence of red conglomerate and red sandstone with minor red mudstone. Conglomerate and sandstone beds vary from 1 cm to several metres in thickness. The conglomerate contains clasts of sedimentary and volcanic rocks, quartz, and feldspar in a muddy to feldspathic sandy matrix. Although red mudstone occurs rarely in the northern part of the basin, it dominates Arthurette rock types in the south. The mudstone is thin to thick bedded, locally contains up to 10% pinkish grey, nodular limestone, and displays poorly preserved mudcracks.

Minor amounts of buff to grey, calcareous, quartz-pebble conglomerate interbedded with sandstone occur toward the stratigraphic top of the unit. These rocks grade into siliciclastic rocks.

Plaster Rock Formation (Units Ms_2 and Ms_3): The Plaster Rock Formation is restricted to the central part of the Plaster Rock Basin (Figure 3). It is divided into a lower, predominantly limestone unit interbedded with shale (Ms_2), and an upper unit of gypsum, gypsiferous siltstone, and shale (Ms_3). The thickness of the Plaster Rock Formation has been estimated at 150 to 300 m (St. Peter 1979).

The limestone–shale unit occurs in scattered outcrops, mostly in the southern and western parts of the basin. Limestone is greenish grey to dirty white to reddish brown, very fine grained, and massive to nodular. The nodular limestone occurs in lenticular beds ranging in maximum thickness from 1 to 20 cm. Nodules are generally enveloped by red and green shale. Where shale is abundant, the limestone has a red, streaky, and patchy-mottled appearance. Near the mouth of Salt Brook on the east bank of the Tobique River (Plate 92-49B), shallow-dipping massive limestone beds are up to 10 cm thick. These rocks grade laterally into nodular limestone. The nodules are interpreted to have a diagenetic origin, i.e., a product of calichification (St. Peter 1979). Red shale beds, up to 2 m thick, are intercalated with the limestones throughout the sequence. Locally, the shales display reduction spots and mudcracks.

Red shale with interbeds of gypsiferous shale and gypsum overlie the limestone–shale sequence and are the youngest Mississippian rocks in the Plaster Rock Basin. Although this unit is not well exposed, a few good sections can be seen on the banks of the Tobique River just east of Plaster Rock and along Route 109 near Wapske. The presence of underlying gypsiferous strata is also suggested by numerous sinkholes at various locations throughout the basin (Hamilton 1965).

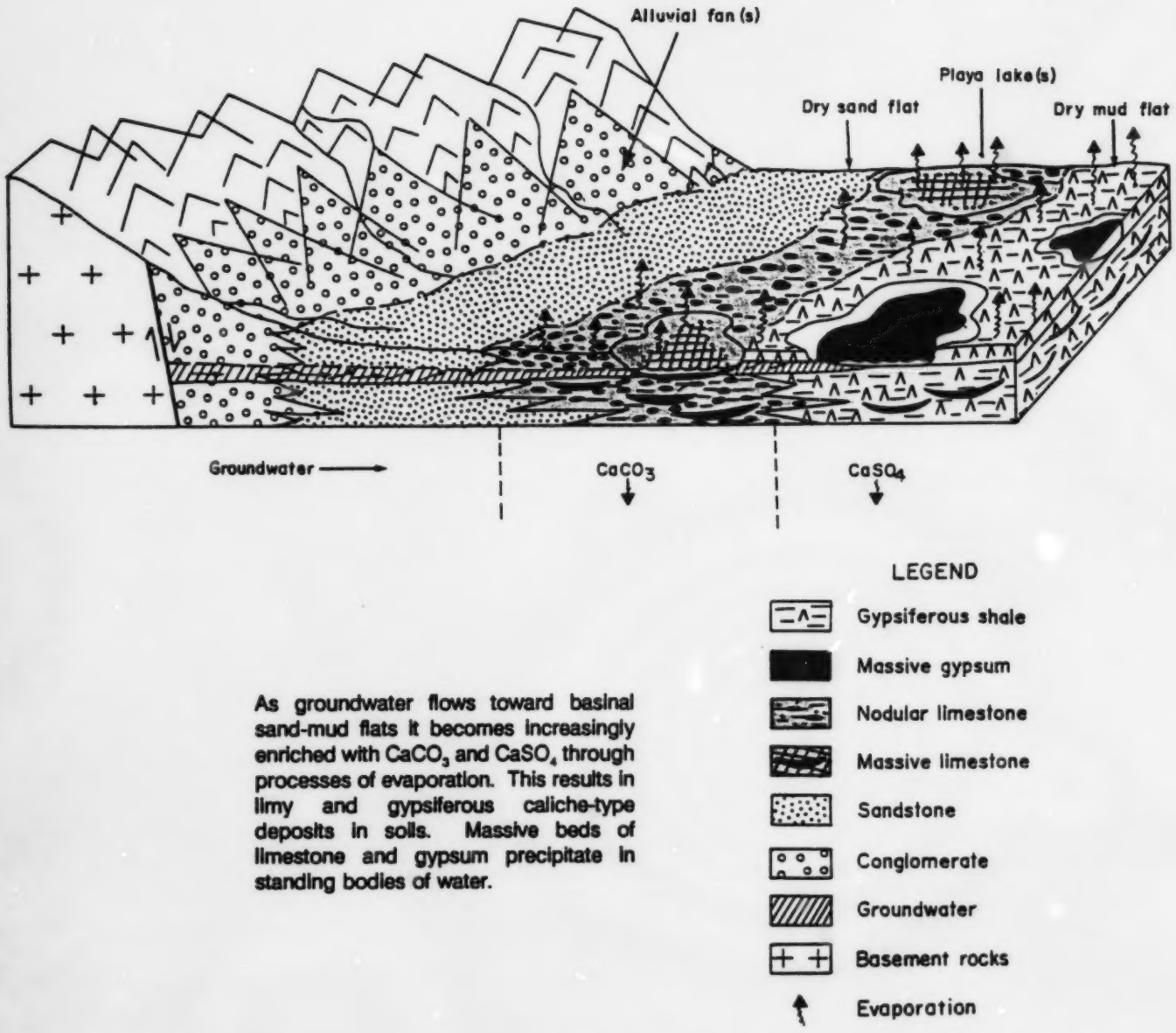
The gypsiferous strata has an estimated thickness of 40 m (Hamilton and Barnett 1970). Individual beds vary in thickness from a few centimetres to about 1 m, rarely exceeding 2 m. Gypsum, which is less abundant than shale, occurs in white to dirty white and reddish white beds varying in thickness from less than a centimetre to about 1 m. The variation in thickness is due to the lenticular nature of the beds, which often places restrictions on the lateral extent of the more massive gypsum deposits. In places, gypsum is disseminated in a shaly/muddy matrix and forms coalescing nodules with thin intervening films or layers of shale. Gypsum also occurs as fine, fibrous "satin spar" in 1 to 5 cm wide veins often orientated parallel to subparallel to the bedding in shaly host rocks. The disseminated nature of the gypsum, its porphyroblastic mode of occurrence, and a slight discordance between shale and gypsum bedding planes suggest that it is probably of diagenetic origin (St. Peter 1979). Most of the gypsum is thought to have resulted from intrasediment precipitation, which has created both displacive and incorporative gypsum crystals in the shales (or muddy and silty sediments) of the Plaster Rock Formation, as opposed to precipitating on the surface of the sediments. Other more massive gypsum deposits most likely precipitated from isolated ponds or playas (Figure 4).

Age and Depositional Synthesis of the Plaster Rock Formation: The paleo-environment of Carboniferous sedimentarty rocks in the Plaster Rock Basin has been discussed by several workers (Rose 1936; Sund 1958; Webb and Kingston 1975, St. Peter 1979). According to St. Peter (1979), the Arthurette Redbeds represent alluvial-fan deposits that evolved in a fault-controlled, graben-like (or half-graben) structure. The Plaster Rock Formation is interpreted as fluvial overbank and playa mud flat deposits near the distal boundary of the alluvial fan that developed under the influence of semi-arid climate (Figure 4). These deposits are characterized by diagenetic limestone (caliche) in the lower part of the formation overlain by diagenetic gypsum and gypsiferous shale (gypcrete). Carbonate- and sulphate-rich groundwater apparently became increasingly concentrated as it progressed across mud flats, resulting in the eventual nucleation of carbonate and sulphate into nodules and the subsequent formation of irregular lenticular layers. Locally, the evaporation of standing surface waters on the mud flats (ponds) resulted in thin-bedded and mosaic deposits of higher-quality gypsum. However, the lateral extent and thickness of these deposits are expected to be rather limited in such an environmental setting.

No fossils have been found in the Carboniferous rocks of the Plaster Rock Basin. However, they are assigned a Mississippian age on the basis of their stratigraphic position, unconformable relationship with underlying Devonian strata, and general lithologic similarities to Mississippian strata in southern New Brunswick.

PENNSYLVANIAN

Conglomerate and Sandstone (Ps): In the central part of the basin, the Plaster Rock Formation is conformably overlain by red conglomerate and sandstone (Figure 3). These rocks are correlated with basal strata of the Pennsylvanian Petitcodiac Group in the Moncton Subbasin of southern New Brunswick (Sund 1958). Fragments of fossilized plant material (i.e., Calamites sp.) identified in float from the area tends to support a Pennsylvanian age for these rocks.



As groundwater flows toward basinal sand-mud flats it becomes increasingly enriched with $CaCO_3$ and $CaSO_4$ through processes of evaporation. This results in limy and gypsiferous caliche-type deposits in soils. Massive beds of limestone and gypsum precipitate in standing bodies of water.

Figure 4. Geologic model depicting a depositional synthesis of the Plaster Rock Formation, Victoria County, New Brunswick.

STRUCTURE

The structural geology of the study area has been described in detail by several workers (Sund 1958; Hamilton 1965; St. Peter 1978, 1979, 1981; Wilson 1988, 1990). The pre-Carboniferous layered rocks have been folded during the Taconian (Middle to Late Ordovician) and Acadian (Late Devonian) orogenies. Sedimentary rocks display a moderately to well-developed cleavage; in associated volcanic rocks, cleavage is poorly to moderately developed. Intrusive rocks do not show cleavage. In the Devonian rocks of the region, cleavage strikes approximately northeast and dips at moderate to steep angles to the southeast and, locally, to the northwest.

Carboniferous rocks in the Plaster Rock Basin show no evidence of deformation (i.e., folding or cleavage). Beds seldom dip more than 15°.

Faults are an important structural feature of the study area (Plates 92-49A and 92-49B). Several have been identified and traced on the basis of topography, contrasting lithological relationships (discontinuities), aeromagnetic signatures, displacement on dykes and/or sills, and other criteria (St. Peter 1979; Wilson 1990). With the exception of the east-trending Catamaran Fault (St. Peter 1979), most of the major faults are located in the western part of the study area. The Rocky Brook–Millstream Fault (Skinner 1953), a major transcurrent fault that can be traced for several hundred kilometres, cuts across the northwestern part of the study area. The Blue Bell Fault (Wilson 1990), a splay of the Rocky Brook–Millstream Fault, juxtaposes Silurian–Devonian rocks against Carboniferous strata. A number of northwest-trending faults offset Devonian volcanic and sedimentary rocks in the Blue Mountain–Riley Brook area (Wilson 1990). The North View and Sisson Ridge faults appear to be the youngest faults in the region. They are syn- or post-Carboniferous structures offsetting Carboniferous strata in the western half of the Plaster Rock Basin (St. Peter 1979).

SURFICIAL GEOLOGY

The Plaster Rock Basin and adjoining areas described in this report are part of the Chaleur Uplands physiographic region (Bostock 1970; Rampton *et al.* 1984). Landforms and the distribution of surficial materials have been influenced by southerly to southeasterly ice flow moving from the North Maine Ice Divide (Rappol 1986a, 1986b, 1988) and the Laurentide Ice Sheet during Late Wisconsinan time (Rampton and Paradis 1981).

At the commencement of deglaciation, various types of morainal till were deposited from meltwater heavily charged with sediment. In the survey area, the four types of surficial deposits recognized are: (1) alluvium, (2) glaciofluvial deposits, (3) ice-contact deposits, and (4) ablation till (Thibault 1980).

During Holocene time, a postglacial warming trend continued to shape the landscape of the study area. The land surface was subjected to weathering processes that resulted in the development of a karst topography in parts of the Plaster Rock Basin. During the same period, soil formation, incision of modern streams, deposition of alluvium, and accumulation of organic material in low-lying areas occurred (Millette and Langmaid 1964).

ECONOMIC GEOLOGY

Among the most recognizable mineral resources of the Plaster Rock Basin and surrounding area are nonmetallic mineral deposits such as limestone, gypsum, surficial deposits (granular aggregates), bedrock aggregate, and several metallic mineral occurrences containing base metals and/or precious metals. The limestone, gypsum, and granular aggregate deposits have had histories of limited development. Most recently, the search for metallic mineral deposits in the region has intensified. The discovery of base metal mineralization near Sewell Brook in 1990 has sparked a great deal of interest, as indicated by the significant increase in the number of mining claims recently staked in the region.

NONMETALLIC MINERAL DEPOSITS

LIMESTONE

Limestone deposits in the Plaster Rock Basin have been known since the early eighteenth century. In fact, until the 1940s Plaster Rock limestone was used periodically as a local source of agricultural lime. The limestone deposits have been described by several workers (Hind 1865; Bailey and McInnis 1887; Goudge 1934; Robb 1870; Rose 1936; Wright 1944, 1945; Hamilton 1965; and Webb and Kingston 1975). More recently, descriptions of these deposits have been given by St. Peter (1979) and Webb (in press).

Limestone exposures are restricted to the western and southern half of the Plaster Rock Basin, along the Tobique and Wapskehegan rivers (Figure 3, Plate 92-50B). Most are located within a 10 km radius of the village of Plaster Rock. Localities considered in the current mineral resource inventory include Armstrong Crossing, Wapske, Plaster Rock, Little Burntland Brook, and Oxbow.

Armstrong Crossing: This deposit, also referred to as the Wapskehegan River deposit, has been the subject of several studies. In fact, it is one of the few deposits in the region with a history of production. For example, the Day Quarry (circa 1930s) is located between the Wapske River and the Canadian National Railway line, about 3 km southeast of the community of Wapske (Plate 92-50B). Overburden thickness in the vicinity of these old workings is variable but is considered to be less than 10 m. The land surface adjacent to and south of the Wapske River gradually rises to a height of approximately 10 m above the river level at Armstrong Crossing. Discontinuous and scattered outcrops of limestone and red shale are exposed in this area. The

limestone-bearing strata dip 3° to 5° to the north. According to Goudge (1934), typical limestone beds are about 1 to 2 m thick and have a rubbly to nodular appearance on weathered surfaces. This nodular habit is attributed to varying amounts of red shale, occurring as disseminations, and interbeds that seldom exceed 60 cm in thickness. The limestone is generally greenish grey, except near its contact with shales where a red mottling is characteristic.

The limestone at Armstrong Crossing seldom exceeds 51% Ca0 (Table 2 and Plate 92-50B). High-grade zones may occur but they are expected to be of limited extent. For example, Goudge (1934) reported that a composite sample representing a vertical distance of about 6 m was collected in the vicinity of the Day Quarry. Analysis of this sample is as follows: CaO–50.89%; SiO_2–4.80%; Fe_2O_3–0.60%; Al_2O_3–1.96%; $Ca_3(PO_4)_2$–0.15%; MgO–0.54%; and S–trace. It is not known whether the analysis was performed on limestone nodules and associated shaly material or on only the limestone nodules. Low Al_2O_3 values would tend to support the latter conclusion.

About 10 years after Goudge's assessment, a shortage of agricultural lime in northwestern New Brunswick prompted the Provincial Government to conduct a re-evaluation of the Armstrong Crossing deposit. A two-stage exploration programme over a 16.2 ha site was initiated. During the first stage, chip samples from several exposures were analyzed and found to contain an average of 50% CaO. The second stage consisted of the drilling of three holes for a total depth of 42 m in order to verify the deposit's thickness and grade continuity at depth. Although two holes intersected limestone horizons with thickness up to 4 m and grades of 45 to 50% CaO, no further work was recommended.

The development potential of the deposit in the vicinity of the Day Quarry was reconsidered by Hamilton (1965) of the Department of Lands and Mines. He estimated the reserves to be 1 800 000 t of 80% $CaCO_3$ (45% CaO).

Wapske: Outcrops of interbedded limestone and red shale, dipping 5° to 15° toward the east, are exposed on the banks of the Tobique River and along the main rail line of the Canadian National Railway west and south of the community of Wapske (Figure 3, Plate 92-50B). Thin interbeds and partings of red shale constitute a significant portion of most outcrops. Analysis of several limestone nodules from the area showed that CaO content is seldom more than 50% (Table 2; and Plate 92-50B).

Limestone, similar to that exposed west of Wapske, is believed to underlie an extensive area south of the community. However, the scarcity of outcrops, the inaccessibility of the area, and the anticipated low and variable CaO content of the limestone all contribute to the general lack of interest in this area as a potential exploration target.

Plaster Rock: Interbedded nodular limestone and red shale, similar to that at Armstrong Crossing and Wapske, occur in and around the village of Plaster Rock. Exposures can also be seen on the east bank of the Tobique River immediately north of the mouth of the Salt Brook (Plate 92-50B). Grab samples of limestone nodules from several outcrops have yielded CaO values less than 50% (Table 2). The predominance of red shale disseminations and interbeds in

TABLE 2. Chemical Analyses of Limestone Samples from the Plaster Rock Basin, Victoria County, New Brunswick (for locations, see Plate 92-50B)

SAMPLE NO.	SiO_2	Al_2O_3	Na_2O	K_2O	Fe_2O_3	L.O.I.	MgO	CaO	NAME OF DEPOSIT
WPK-1.1-90	10.64	2.36	0.22	0.40	1.10	36.79	1.22	45.76	
WPK-1.2-90	4.48	1.24	0.06	0.24	1.08	40.37	0.08	52.72	
WPK-1.3-90	6.72	2.10	0.08	0.34	0.73	39.56	1.08	52.05	
WPK-1.4-90	6.64	2.06	0.08	0.32	0.90	39.16	1.10	51.26	
WPK-1.5-90	5.84	1.42	0.06	0.28	1.00	39.89	0.94	51.26	
WPK-1.6-90	8.68	1.98	0.20	0.36	1.14	37.90	1.08	49.66	
WPK-1.7-90	5.76	1.18	0.08	0.26	1.04	40.01	0.54	52.90	
WPK-2.1-90	11.96	2.30	0.10	0.44	2.02	36.28	1.20	46.84	
WPK-2.2-90	12.72	2.98	0.10	0.40	1.02	35.69	1.74	46.98	
WPK-3-90	29.20	5.22	0.08	0.80	3.06	27.55	1.52	31.40	
WPK-4-90	20.60	4.88	0.10	0.80	2.68	30.90	1.48	37.74	
WPK-5-90	11.36	3.01	0.08	0.50	1.32	36.90	1.06	47.80	
WPK-6-90	7.92	1.52	0.08	0.24	0.70	38.49	1.10	50.46	Armstrong Crossing
WPK-7-90	5.72	1.42	0.06	0.24	0.72	39.50	1.04	52.52	
WPK-8-90	6.80	1.36	0.04	0.20	0.90	39.00	0.96	51.72	
WPK-9-90	7.76	1.66	0.04	0.26	0.58	38.99	1.14	50.42	
WPK-10-90	3.64	0.74	0.06	0.16	0.34	38.92	0.82	55.86	
44-14	-	0.98	-	-	-	-	0.57	51.40	
44-14A-B	-	1.54	-	-	-	-	1.10	51.14	
44-14C	-	1.34	-	-	-	-	0.80	49.88	
44-14D	-	1.58	-	-	-	-	0.78	50.56	
61-13	6.7	1.40	-	-	-	-	0.74	49.4	
61-13A	2.8	1.20	-	-	-	-	2.00	49.6	
PR-32	-	-	-	-	-	-	-	48.20	
PR-35	-	-	-	-	-	-	-	40.52	
PR-37	-	-	-	-	-	-	-	37.53	
G-5	4.80	1.96	-	-	-	-	0.54	50.89	
PR-11	-	-	-	-	-	-	-	44.92	Wapske
PR-14	-	-	-	-	-	-	-	39.21	
PR-15	-	-	-	-	-	-	0.34	41.68	
TB-2.1-90	8.64	1.78	0.10	0.36	0.82	40.24	1.78	48.96	
TB-2.2-90	16.60	2.36	0.10	0.62	1.50	33.87	1.32	42.88	
TB-2.3-90	19.08	3.10	0.12	0.66	1.58	32.35	1.32	40.94	
TB-2.4-90	19.12	3.10	0.12	0.66	1.52	32.38	1.32	41.40	Plaster Rock
TB-2.5-90	15.08	4.08	0.08	0.68	1.78	34.32	1.22	45.00	
G-4	17.94	2.83	-	-	-	-	0.66	42.76	
PR-6	-	-	-	-	-	-	-	48.14	
PR-20	-	-	-	-	-	-	-	41.51	
PR-27	-	-	-	-	-	-	-	46.36	L. Burntland Brook
OXB-1A-90	20.28	5.06	0.12	0.84	1.92	31.54	1.70	38.92	
OXB-1B-90	20.36	3.56	0.14	0.44	1.22	34.09	10.54	28.62	
G-6	9.08	2.59	-	-	-	-	0.72	47.67	Oxbow
61-14	16.50	4.10	-	-	-	-	1.7	44.7	
PR-10	-	-	-	-	-	-	-	45.26	

most outcrops would tend to have a negative impact on overall limestone quality unless a suitable upgrading technique could be utilized. Apart from suspected grade control problems, the location of the resource with respect to nearby habitation and the Tobique River are among the most significant factors detracting from any future development considerations.

Little Burntland Brook: Reddish grey to greenish grey limestone is exposed just east of the Tobique River along Little Burntland Brook, approximately 11 km north of Plaster Rock (Figure 3). The massive nature of this limestone occurrence distinguishes it from the typical nodular limestone–red shale deposits in the vicinity of Plaster Rock, Wapske, and Armstrong Crossing. The occurrence at Little Burntland Brook consists of a limestone bed, probably no more than 2 m thick, sandwiched between two red and grey sandstone and shale units. Analysis of a few limestone grab samples revealed less than 50% CaO (Table 2). The lateral extent of this deposit is unknown.

Oxbow: Approximately 200 m north of the Riley Brook–Plaster Rock Highway, scattered outcrops of reddish grey to greenish grey limestone occur on the southern shore of a small lake at Oxbow (Figure 3). At one time, a small limestone operation, locally referred to as the Alton Quarry, was active at the site where a 3 to 4 m thick ledge of flaggy to massive-bedded limestone is interbedded with reddish grey to greenish grey calcareous sandstone, shale and minor conglomerate. The quarry supplied lime for local agricultural use but has been abandoned for many years. A few limestone grab samples indicate CaO values less than 45% (Table 2).

Resource Evaluation: The results of the mineral resource inventory conducted at five localities in the Plaster Rock Basin indicate that: (a) the overall CaO content is relatively low and inconsistent, requiring some form of upgrading to meet industry standards for most applications; (b) bed thicknesses of massive limestone units and their lateral extent are extremely variable; and (c) most limestones are of the nodular variety with thin shaly films or intercalations. Apart from qualitative concerns, proximity to habitation, major watersheds and public roads and highways are some of the other constraints affecting potential development.

Limestone Uses and Specifications: Limestone and its derivatives are among the most versatile mineral commodities extracted from the earth's crust. It is present, in one form or another, in most manufactured products and/or activities known to man.

It is beyond the scope of this report to provide a complete list of limestone uses and raw material specifications. However, some of the more common applications and raw material requirements are summarized in Table 3.

With the possible exception of agricultural lime, it appears that most limestone in the Plaster Rock Basin would not meet required minimum specifications for most industrial applications without considerable upgrading. This would be a difficult undertaking, adding considerable cost to potential manufactured products, making them uncompetitive with similar materials already in the market place.

TABLE 3. Common Uses and General Specifications for Limestone/Lime

APPLICATION	FUNCTION	GENERAL SPECIFICATION	REFERENCE
Soils (lime)	Soil stabilization	*Chemical:* Min. 90.0% Ca and Mg oxides (on loss-on-ignition-free basis); max. 5.0% CO_2 (at point of manufacture). *Physical:* **Hydrated lime** ≤3% retained on No. 30 (590 μm) sieve and ≥25% on No. 200 (74 μm) sieve; **Quicklime** all pass a 1.0 (24.4 mm) sieve	American Society for Testing Materials (ASTM) C977-83a
Industrial products (carbonate)	Filler in vinyl floor covering, carpet backing, rubber, synthetic marble, and asphaltic, construction and coal dusting products	White, grey, buff, and off white; 80-95% between 40 and 325 mesh; 95.0-98.0% CaO_3; 0.6-3.0% $MgCO_3$; ≤0.06% Fe_2O_3; ≤0.36% Al_2O_3; 0.02-0.15% H_2O	Guillet and Kriens (1984)
Steel making (lime)	Refractory flux	74% minus 38 to 13 mm; <10% 44 to minus 7 mm; 93.0-95.0% CaO; 1.5% MgO; 0.03-0.04% S; 1.0-1.5% SiO_2; 2.5-4.0% loss on ignition *Reactivity rate* 60°C/minute	Baker (1986)
Chemical process stone (as limestone)	Pulp and paper mills	3/8-1¼"; 50-53% CaO; 0.6-0.7% MgO	Davis (1987a and b)
Agriculture	Soil sweetener	0.1-0.8 mm; 44.9-52.7% CaO; 0.4-8.72% MgO	Davis (1987a and b)
Crushed stone in construction	Concrete aggregate (coarse) Bituminous aggregate (coarse) Stone sand-concrete–crushed fine aggregate from quarried stone Stone sand-bituminous mix or seal Combined, coarse and fine aggregate Unpaved road surfacing	90-4.75 mm 90-4.75 mm 4.75-0.074 mm 4.75-0.074 mm 50-0.074 mm 25-0.074	ASTM C33-78 ASTM D692-79; D448-90 ASTM C33-78 ASTM C33-78 ASTM C33-78 ASTM C33-78
Environmental (lake and stream liming)	pH control	0.0-0.4 mm; ≤5% MgO; 85-95% $CaCO_3$; max. 5% MgO + insol.; 100% minus 2 mm	Swedrup (1986) Harben (1992)
Mariculture		100-200 g/m^2 burnt lime	Nishimura (1986)
Water treatment	Purification, softening	Min. 93.0% CaO + MgO; 68.1-90% available CaO	ASTM 53
Flue Gas Desulphurization	Sulphur removal from stack gases of coal-fired electric generating stations	<2% SiO_2; <1% Fe_2O_3; <1% Al_2O_3; 90-95% $CaCO_3$; <2% MgO; <1000 ppm Cl *Reactivity*: min. 50% in 0.5 hr.; min. 90% in 1.5 hr. *L.A. Abrasion*: max. 45 *Bond Work Index*: min. 9.5 at 200 mesh; max. 12 at 200 mesh	Harben (1991) Harriman (1989)
Animal Feed Supplement	Nutrient supplement	95% $CaCO_3$; max. 2% Mg; max. 10 ppm Pb; max. 10 ppm As; max. 2 ppm Hg	Davis (1987a and b)
Glass	Flux	SiO_2 constant: ±0.15%, 0.75% max.; max. 0.085% Fe_2O_3; max. 0.3% Al_2O_3; min. 55% Cao + MgO; max. 0.25% SO_3	Davis (1987a and b)
Cement stone	Basic cement raw material	1.2-23.6% SiO_2; 0.5-3.4% Al_2O_3; 0.4-1.6% Fe_2O_3; 37.4-54.0% CaO; 0.5-0.8% MgO	Clausen (1960)
Sugar refining	Sucrose clarification	Min. 98.5% $CaCO_3$; low silica	Harben (1992)
Pharmaceutical		Min. 98.9% $CaCO_3$; maximum 2% loss on drying; 0.2% insol.; 0.0005% F; 3 ppm As; 3 ppm Pb; 0.05% Fe; 0.5 ppm Hg; 0.002% heavy metals; 1% magnesium and alkali salts	Harben(1992)

Although the region's limestone served as a local source of agricultural lime at one time, it is doubtful whether the resource would meet today's industrial standard of a minimum 85% neutralizing value. To maximize and improve the available lime content, the contaminating shaly material associated with most deposits would have to be removed. Without the implementation of such a beneficiation process, application rates for various crops would have to be dramatically increased for the desired effect. This would result in higher costs to the farmer due largely to increases in transportation and field spreading charges. In addition, the high clay content of an unprocessed product would affect the arability of a field, eventually reducing the effectiveness of fertilizer uptake by various crops. Clays would tend to absorb certain fertilizers constituents and make them unavailable to crops. Therefore, more fertilizer would be required to overcome this effect. Even if the Plaster Rock limestone deposits could be successfully upgraded to acceptable ag-lime standards it could only be expected to supply the local market in the potato belt of northwestern New Brunswick and northern Maine. Attempts to market in this region would be met by stiff competition from other provincially based ag-lime producers already supplying the region. The Agricultural Lime Assistance Program managed by the New Brunswick Department of Agriculture would negate any potential transportation advantage of a potential Plaster Rock producer. Essentially, the program rebates the farmer part of the cost of transportation of lime from a New Brunswick producer. For example, the greater the distance from the producer to the farmer, the greater the subsidy (e.g., if the distance hauled is 0-40 km, the rebate is $2.76 per tonne; for 181-190 km, the rebate is $7.00 per tonne). Therefore, the proximity of Plaster Rock to the proposed market area would not be a significant advantage as long as the policy remains in effect.

GYPSUM

Gypsum deposits in the Plaster Rock Basin have been described by several workers (Bailey 1885, 1886, 1899; Bailey and Jack 1906; Bailey and McInnes 1887; Jennison 1911; Kramm 1912; Cole 1930; Rose 1936; Sund 1958; Hamilton and Barnett 1970; Webb and Kingston 1975; and St. Peter 1979).

The history of production from the Plaster Rock deposits extends back to the nineteenth century when it was used as a soil conditioner, commonly referred to as "land plaster" (agricultural gypsum). Records indicate that a rail line linking Plaster Rock and Perth was used to transport gypsum to various destinations in New Brunswick and adjacent areas in Maine, U.S.A. Among the earliest gypsum operations was one owned by a local enterpreneur, John Edgar, who had set up a grinding mill at the village of Plaster Rock prior to 1880. The production of agricultural gypsum increased at Plaster Rock with the establishment of the Tobique Valley Mining and Manufacturing Company in 1893. Following its demise, due to increased cost of transportation and other problems, the Stinson-Reeb Supply Company quarried gypsum for use in the manufacturing of cement at Montreal. This company ceased operations in the late nineteenth century. No production has been reported from the region since that time.

Most gypsum exposures are located in the immediate vicinity of the village of Plaster Rock. They form prominent cliffs along Tobique and Wapske rivers, and outcrops near an abandoned airstrip east of the village. The gypsiferous rocks are poorly exposed elsewhere, but due to the

widespread distribution of sink holes, the extent of these deposits can be inferred to cover an area of about 20 km^2. The general geological setting and description of these deposits have been addressed earlier in this report.

Table 4 gives partial analyses of five grab samples of gypsiferous material from the Plaster Rock area. For some samples, the exact location and a complete description of the material sampled is not known. Most contain less than 90% gypsum.

TABLE 4. Chemical Analyses of Gypsum Samples from the Plaster Rock Basin, Victoria County, New Brunswick

Sample No. or Locality	Insoluble	Fe_2O_3	Al_2O_3	CaO	MgO	SO_4	H_2O	CO_2	K_2O + Na_2O	SiO_2	$CaSO_4$ $2H_2O$	Reference
1. Exact Location Unknown	8.86		2.72	27.92	1.96	38.21	17.80	2.39	-	-	85.06	Jennison 1911
2. Exact Location Unknown	1.18		9.80	28.95	trace	41.06	18.45	0.58	-	-	88.16	Jennison 1911
3. Exact Location Unknown	7.36	0.61	2.09	29.56	0.84	39.54	18.08	1.54	-	-	86.39	Cole 1930
4. SB-GYP-1-90*		0.34	0.54	29.78	0.36	51.77	18.79	-	0.22	1.80	91.84	current study
5. WPK/GYP-11/90*		0.34	0.66	28.66	0.58	51.84	18.32	-	0.24	4.00	90.64	

*For location see Plate 92-50B

In 1990, Plaster Rock resident Dan Merrithew (The Cataract 1992) renewed interest in the region's gypsum deposits when he staked an area near the abandoned Plaster Rock airstrip, east of Little Arbuckle Brook. Work on the property consisted of stripping and trenching and eleven air-track drill holes. The drill holes were randomly spaced over a 2 to 3 ha site and drilled to depths ranging from 3 to 30 m. Table 5 gives paritial analyses of seventeen powder samples of drill cuttings from these holes. Keeping in mind that the drilling method probably caused contamination of the samples, most of the recovered gypsiferous material was reddish white to reddish brown and seldom exceeded 75% gypsum. Intervals of white gypsum, with up to 85% gypsum present, were intersected in three holes.

Resource Evaluation: In general, the quality and extent of gypsum in the Plaster Rock Basin appears variable and erratic. Its compositional variations are due to contamination and dilution by red and green shale or clay. As described previously, gypsum occurs as thin nodular to massive beds often interbedded and intercalated with variable amounts of shale, so that the gypsum content probably accounts for only a small portion of the gypsiferous strata by volume. Hamilton and Barnett (1970) gives an estimated reserve of 150 000 000 t of gypsiferous material in the Plaster Rock Basin. However, the economically recoverable portion of this reserve is far less due to its location and the nature of its occurrence.

TABLE 5. Partial Chemical Analyses* of Air Track Drill Cuttings from an Area East of the Village of Plaster Rock, Victoria County, New Brunswick

Drill Hole No.	Interval Sampled (m)	Colour of Powder	$CaSO_4$ as Received (%)	$CaSO_4$ Dry (%)	Moisture (%)	Insolubles (%)
1A	0 - 1.52	white	72.42	85.60	15.4	3.98
1B	1.52 - 3.04	white	67.17	78.75	14.7	8.84
1C	3.04 - 4.57	reddish white	44.93	50.26	10.6	23.33
1D	4.57 - 6.09	reddish white	41.97	47.37	11.4	21.80
2	0 - 6.09	white	72.57	85.81	15.5	3.33
3A	0 - 6.09 (top of hole?)	light brown	62.08	71.44	13.1	9.59
3B	0 - 6.09 (bottom of hole?)	reddish white	64.12	74.21	13.6	12.44
3C	6.09 - 9.14	reddish white	54.23	61.56	11.9	17.27
3D	11.58 - 12.19	reddish white	37.99	44.47	8.4	30.92
4	6.09 - 9.14	reddish white	36.05	40.05	10.0	28.58
5	0 - 12.19	reddish brown	47.05	53.34	11.8	21.34
7	0 - 2.74	light brown to reddish brown	65.52	75.48	13.2	12.39
8	0 - 1.52	light reddish brown	65.50	75.46	13.2	11.71
10	0 - 1.83	light brown to reddish brown	66.11	77.56	14.8	8.49
11A	0 - 1.22	reddish white	60.84	70.01	13.1	13.07
11B	1.22 - 2.74	reddish white	61.99	70.76	12.4	11.51
11C	6.09 - 10.67	reddish white	66.96	77.41	13.5	9.93

* Analyses were provided by Mr. Dan Merrithew, a resident of Plaster Rock, Victoria County, New Brunswick

Gypsum Uses and Specifications: Like agricultural lime, gypsum is a low-cost, high-tonnage commodity that generally requires an intergrated mine and product-manufacturing facility strategically located for a given market area. Gypsum is widely used in the manufacturing of several end products. Some of the many uses for gypsum include: cement, agriculture, fillers, chemical and pharmaceutical applications, wallboard manufacture, building plasters, road repair, and oil well casing cements. Specifications for the various end products are diverse. A few of the more popular applications are included in Table 6 to assist the reader in assessing the quality and development potential of the gypsum resource in the study area.

For gypsum plasters and cement, the specifications are set by the American Society for Testing and Materials (ASTM) and the Canadian Standards Association (CSA). Chemical purity standards for wallboard demand a minimum of 85% gypsum. For the most part, Plaster Rock gypsum fails to consistently satisfy the minimum criteria for such an application. Gypsum used for agricultural purposes (ag-gypsum) does not require high purity; however, specifications call for material with a particle size in the range of 0.15 to 1.00 mm (New Brunswick Department of Agriculture 1991). Gypsum provides a source of calcium and sulphur trioxide. It combines with potassium aluminum silicates in soil to reduce the potassium to a more soluble form for uptake by plants. It also assists in breaking hard soils for better aeration, water penetration, and retention.

The application of gypsum to soils usually results in increases in crop yields. This is particularly evident for potatoes, fruits, and vegetables. Gypsum is also used to treat animal manures. The application of 158 kg of gypsum per tonne of fermenting manure not only controls unpleasant odours but also fixes organic sources of nitrogen as ammonium sulphate, which is often utilized as a soil amendment. Nitrogen is an extremely important nutrient for plant growth. Table 7 displays typical gypsum applications for several crops as recommended by gypsum producers in the United States and the New Brunswick Department of Agriculture.

Provided Plaster Rock gypsum would meet agricultural specifications and assuming a application rate of 562 to 1125 t/1000 ha of potatoes (Haines Technology Associates and Bezys 1990), a potential market in the northwestern potato producing counties of Carleton, Victoria, and Madawaska would probably be less than 20 000 t (Table 8). If a similar level of consumption is realized for the potato crops in northern Maine, a total market in the order of 40 000 t may be reasonably accessible to a prospective Plaster Rock producer. Potatoes are not the only crop in this part of northwestern New Brunswick that would benefit from the application of agricultural gypsum. Grains, forages, and vegetables have a very significant presence in the region and offer the possibilty of further expanding the ag-gypsum market. The impact of these crops on ag-gypsum demand is highly speculative. However, a review of the number of hectares planted in 1990 (New Brunswick Department of Agriculture 1990) and a rate of application near 1000 kg/ha indicate a potential ag-gypsum market in the range of 60 000 t (Table 8).

It appears that the market potential for agricultural gypsum in western and northwestern New Brunswick may be in the order of 80 000 t. However, it should be emphasized that this is a "potential" market projection and is based on rather broad generalizations. Therefore, it must be considered nothing more than speculation at this point, requiring verification by a more detailed analysis.

TABLE 6. Common Uses and General Specifications for Gypsum

APPLICATION	GENERAL SPECIFICATION(S)	REFERENCE(S)
Wallboard	Moisture content – max. 15% $CaSO_4 \cdot 2H_2O$ – min. 85% (94-95% preferred) $CaSO_3$ – 0.5-2% Cl – max. 400 ppm; Na – max. 250 ppm Mg – max.250 ppm; K – 75 ppm Average particle size – 20 microns	Harben (1992);
Agriculture	$CaSO_4 \cdot 2H_2O$ – >70% Moisture content – <10% Cl – <1% Ca^{++} – >20%; S – >15% All particles passing 16 mesh screen and 50% passing 100 mesh screen	Harben (1991) New Brunswick Department of Agriculture (1991)
Cement	65% gypsum ± 5% anhydrite 52% ± 2% SO_3 2% retained on a 4 mesh screen	Haines Technology Associates and Bezys (1990)
Filler	$CaSO_4 \cdot 2H_2O$ – 97% Brightness – 97%+	Harben (1992)
Food and Pharmaceuticals	(typical) $CaSO_4 \cdot 2H_2O$ – 96.75% As – max. 3 ppm; Se – max. 30 ppm; F – max. 30 ppm; heavy metals – 10 ppm; iron – 100 ppm; lead – 10 ppm	Harben (1992)

TABLE 7. Typical Crop Application Rates for Agricultural Gypsum

TYPE OF CROP(S)	RATE OF GYPSUM APPLICATION
Alfalfa and clover	2.2 t/ha at time of seeding
Hay and grasses	0.22-0.67 t/ha at time of seeding, plus 0.56-1.11 t/ha after cropping
Wheat	0.33-1.11 t/ha by drilling or broadcasting at seeding
Corn	0.56-1.11 t/ha during ground preparation or drilled at time of seeding
Potatoes	0.56-1.11 t/ha during ground perparation or drilled at time of seeding
Peanuts	0.56-1.11 t/ha during ground preparation or at time of planting
Citrus trees	45 kg/tree

Source: Haines Technology Associates and Bezys (1990)

TABLE 8. Estimated Market Potential for Agricultural Gypsum in Western and Northwestern New Brunswick

Crop	Area Cultivated[1] (ha)	Typical Application Rate[2] (kg/ha)	Ag-Gypsum (t)	Market Share (%)
Potatoes	16 250	562 – **1125**	18 281	24.0
Grains[3]	18 505	337 – **1125**	20 818	27.0
Forage[4]	21 000	**675** (at seeding) **1125** (after cropping)	14 175 23 625	7.5 30.0
Others[5]	1 100	**1125**	1 238	1.5
Total	56 855		78 137	

Note: Numbers in bold print were used to calculate tonnes in the Ag-Gypsum column.
[1] Source: New Brunswick Department of Agriculture (1991)
[2] Source: Haines Technology Associates and R.K. Bezys (1990)
[3] Includes barley, wheat and buckwheat, oats, and rye
[4] Includes alfalfa, grass, corn, pasture, silage, and hay
[5] Includes vegetables (estimated from 1991 data, New Brunswick Department of Agriculture)

Actual levels of ag-gypsum consumption depend on many factors. Soil chemistry (its nutrient difficiencies), local weather conditions, and the ability of the farmer to pay for the material play a major role. The ag-gypsum figures quoted here reflect an ideal supply and demand scenario; real demand in the region would probably be substantially less. At a level 50% of the optimum potential, demand could conceivably approach 40 000 t. The potential demand for ag-gypsum in northern Maine and the rest of New England is not known but it is expected to be considerable (between 30 000 and 40 000 t) and could increase the total regional market by several thousand tonnes.

Many of the same development constraints that apply to agricultural lime production from the Plaster Rock area may also apply to gypsum (i.e., transportation subsidy through Agricultural Lime Assistance Program and quality control).

In addition, natural gypsum may face increasing competition from gypsiferous byproduct materials (desulphogypsum (DSG) originating from flue gas desulphurization (FGD) at coal-fired electrical generating stations. This technology is currently being implemented at two New Brunswick power plants, at Belledune and Dalhousie in northern New Brunswick. The Belledune Power Station is expected to produce in the order of 200 000 t of DSG annually. The marketing of this gypsiferous byproduct is an important part of the waste management strategy for FGD operations (Steffan and Golden 1991). The impact of DSG (Thayer 1991) on natural gypsum markets at the present time is difficult to quantify. Its use as a suitable source of ag-gypsum appears to depend on several factors. These include variable costs associated with the reduction of its free moisture content, its tight particle size distribution compared to natural material, any

hazardous impurities or soluble salts, and success in the power utility securing alternate markets for the material (e.g., wallboard manufacturing). If an acceptable low-cost material can be produced, competition in natural ag-lime and ag-gypsum markets (Pit and Quarry Magazine 1992) is expected to intensify. A small natural gypsum operation (with potentially high production costs) producing one product and totally dependent on one main market area would find it difficult to remain competitive with cheaper byproduct sources. New Brunswick's Agricultural Lime Assistance Program, which subsidizes transportation cost from in-province producers to the farmer, also applies to agricultural gypsum. Therefore, the proximal location of the gypsum deposits with respect to the proposed market area may not be considered a logistical advantage to a potential Plaster Rock producer.

AGGREGATE RESOURCES

Aggregate resources in the Plaster Rock area include a variety of surficial deposits (granular aggregate), and bedrock aggregate.

Granular Aggregate: A comprehensive inventory of granular aggregates in the province has been compiled by the Department of Natural Resources and Energy's Mineral Resources Division. A collection of maps outlining the distribution and classification of these deposits has been published in a compendium entitled "Atlas of Granular Aggregate Resources" (New Brunswick Department of Natural Resources and Energy 1987). The extent, and qualitative and quantitative data pertaining to granular aggregate resources in the Plaster Rock area have been reported by Lavergne and Hunter (1982) and Thibault (1980). Composite maps (Plates 92-52A and 92-52B) have been compiled using the information from these sources.

Basal glacial till (abalation till), and ice contact and glaciofluvial deposits are the main sources of granular aggregates in the study area (Lavergne and Hunter 1982; Thibault 1980). Alluvial deposits of postglacial origin also occur throughout the region. A brief description of each type of surficial material is given below.

Alluvial Deposits Alluvial deposits consist of moderately to well sorted and bedded gravel, sand, and silt. Particles vary from silt to cobble size. Clasts are generally well rounded. Deposits are generally well stratified and often display graded bedding.

Along the Tobique River valley, alluvial deposits are found in lower riverside terraces. Potential reserves are estimated at about 4 000 000 t (Lavergne and Hunter 1982).

Glaciofluvial Outwash Deposits Glaciofluvial outwash material was deposited by glacial meltwaters directly in front of the retreating ice front. In general, two types of outwash are associated with glacial environments – their distribution dependents on topography. One type consists of valley train deposits with steep embankments that characterize glacial valleys. A second type forms broad outwash plains developed in the lowlands at the terminus of wide ice margins. Outwash deposits vary from poor to well sorted and feature horizontal stratification. Outwash plain deposits have moderate to high potential for crushable aggregate; valley train outwash deposits contain a high proportion of crushable aggregate.

In the study area, glaciofluvial outwash plain deposits are distributed along the Tobique River. A large deposit is found near Reeds Island. Other extensive deposits occur near Diamond Island in the vicinity of Burntland Brook, and near Anfield, north and west of Plaster Rock. Potential reserves of this type of aggregate material in the study area is estimated at 12 000 000 to 14 000 000 t (Lavergne and Hunter 1982; Thibault 1980).

Ice-Contact Deposits As the term implies, ice-contact material is deposited by glacial meltwaters in contact with or in proximity to the ice. Due to the rapid fluctuations in discharge and sediment load of meltwater streams, and changing positions of ice margins, ice-contact deposits have a tendency to be variable in composition, as reflected in a wide range of textural and physiograhic features. Typical landforms associated with these deposits include kames, kame terraces, and eskers.

Kames are conical mounds or small hills composed of mainly sand and gravel ice-contact deposits. These landforms are produced by the deposition of sediments in crevasses or depressions in and on the surface of ponded or nearly stagnant ice. After the ice melts, the accumulated material is left behind in the form of isolated or semi-isolated mounds. Kame terraces are formed between a glacier and the side of a glacial valley; deposition takes place subsequent to ice retreat. Terraces tend to have irregular slopes and are commonly pitted with kettles. Kame deposits generally serve as sources of low-grade aggregate.

An esker is an elongated, sinuous ridge of sand and gravel deposited by a stream flowing in or under the stagnant ice of a retreating glacier. Eskers vary in length from less than 100 m to several hundred kilometres. The height of an esker can range from a few metres to 30 m or more. Like kames, eskers commonly are not reliable sources of good quality aggregate material.

Reserves of ice-contact deposits in the study area are estimated to be 12 000 000 to 15 000 000 t (Thibault 1980; Lavergne and Hunter 1982). Significant deposits of this type are found north of South Tilley and north of the Odell River. Most ice-contact material is probably suitable for low-specification uses in the pit-run state. However, washing and screening can be carried out to upgrade this material when higher-quality materials (for concrete and asphalt) are required.

Ablation Till Ablation till, also formed during deglaciation, comprises a mixture of rock fragments ranging in size from boulders weighing several tonnes to tiny clay and colloid particles.

Ablation till is often classified as a low-quality aggregate. It generally can be used as subbase or base material where the conservation of higher-quality material is desirable. Depending on the availability of higher-quality aggregate near construction sites, ablation till deposits can be upgraded at some expense for higher specification uses. Most deposits of ablation till in the study area are found between the Tobique River and the Canadian National Railway south of Plaster Rock (New Brunswick Department of Natural Resources and Energy 1987).

Bedrock Aggregate: During the last decade, bedrock has become an important source of high specification aggregate in the road building and construction industry. Sustained increases in its use is due to shortages of good quality granular aggregate.

The bedrock aggregate resource potential in the Plaster Rock area was partially evaluated during the present study. Areas considered are underlain by rocks of Lower Devonian Tobique Group. Forty-five samples from mafic and felsic volcanic (Dmv and Dfv), sedimentary (Ds), and mafic intrusive (Dm) rocks were collected for qualitative engineering tests. Each sample consisted of approximately 50 kg of unweathered rock fragments. Hand specimens from each sample site were examined to obtain information pertaining to: colour (in wet and dry states), texture, grain size, hardness, acid reaction, foliation, and mineral composition. At the laboratory, bagged samples were broken down to approximately 10 to 15 cm size and then passed through a jaw crusher producing a minus 20 mm size material. Crushed samples were then subjected to several qualitative engineering tests, using the guidelines in the American Society for Testing and Materials (ASTM) handbook. Results of these tests are listed in Appendix A and on Plates 92-51A and 92-51B. Most samples were found to meet specification limits required for concrete and asphalt aggregate.

Qualitative Assessment of Aggregate Deposits: There are several standard procedures and accepted testing methods that assist in the qualitative assessment and evaluation of aggregate resources. While some of these tests are relevant only to granular aggregate, most are commonly applied to bedrock aggregate (crushed rock) as well.

Quality of aggregate materials are affected by grain size, clast lithotypes, and the potential for alkali reactivity in cement. The impact of grain size on the quality of a deposit is evaluated on the basis of: (1) the proportion of fine material; (2) the presence of oversized material; (3) the distribution of various size fractions; and (4) the overall variability of a deposit. A high proportion of fine-grained material (e.g., minus 200-mesh fraction) renders a deposit unsuitable for many uses in the pit-run state. The New Brunswick Department of Transportation (DOT) sets standards on the amount of fines permitted in materials used for specific purposes. The content of fine material in a sample is determined by procedure C117-76 of the American Society for Testing Materials (ASTM) handbook. The DOT standard for subbase and base-course road material is set at less than 10% fines by weight. Material failing to meet this requirement can often be improved by wet sieving. However, this can substantially increase its overall costs. In general, ablation till, alluvial, and some ice-contact deposits are frequently found to contain a high proportion of fine material.

The presence of oversize (coarse) material can cause operational problems without necessarily affecting the quality of aggregate. Boulders and cobbles larger than 10 cm in diameter are often too large for portable crushing equipment. Boulder removal may require earth moving and screening equipment, once again adding to extraction costs.

The variability of a deposit can also create serious difficulties with maintaining DOT material specifications at competitive operating costs. Many ablation till and ice-contact deposits display extreme variability, while glacial outwash tends to be more homogeneous.

The size distribution in a deposit is also subject to DOT specifications. These vary from project to project.

The types of rock fragments in a granular aggregate have a profound impact on its quality. Ideally, fragments should be hard, generally nonfoliated, uncoated, and resistant to chemical and physical weathering processes. However, invariably some fragments (clasts) are present that are considered "unsound." These are likely to perform poorly and tend to weaken structural integrity of a road surface or other civil engineering projects. Tests carried out to assess the soundness of an aggregate include petrographic analysis, the magnesium/sodium sulphate soundness test, and the Los Angeles abrasion test. The value of petrography should not be underestimated. Petrographic information assists in assessing various types of mineralogic alteration and their impact on the structural state of certain rock types, which affect the long-term competency of an aggregate. Other tests often used to evaluate aggregate include: organic impurity, freeze–thaw, absorption and porosity, specific gravity, stripping, and mortar strength. The procedure and methodology used in conducting these tests are documented in the American Society for Testing and Materials (ASTM) annual handbooks.

Rock fragments with typically high soundness ratings include: diabase, granite, gabbro, hard gneissic rock, basalt, andesite, and wacke. Rocks with a "fair" soundness rating include some types of conglomerate, schist, limestone, and dolomite. Rocks rated as "poor" consist of argillite, chert, slate, volcanic tuff, and friable sandstone.

Mineral–Cement Reactions Not all aggregate is suitable for concrete. Certain aggregate materials react with the alkalies in cement (Na_2O and K_2O) producing an undesirable expansion that leads to premature cracking and deterioration of concrete structures. Cracking also permits water to migrate into the concrete resulting in increased saturation and reduced freeze-thaw durability. Although the impact of this phenomenon can be regulated through the use of low-alkali cement and other corrective measures, it is probably more cost effective to use a nonreactive aggregate. It is important that potentially reactive aggregates are recognized and properly investigated before they are used in concrete.

Mineral–Bitumen Reactions Mineral-bitumen reactions must also be considered in the evaluation of aggregate. Typically bitumen has a slight negative charge and is attracted to the positive charge of rock surfaces rich in ferromagnesian minerals. Therefore, basaltic and gabbroic rock types bind well with bitumen. Acid igneous rocks tend to be negatively charged and aggregates containing considerable amounts of feldspar and quartz in the form of large crystals do not bind well with bitumen.

The Plaster Rock Basin study area appears to have an ample supply of fair to good quality granular aggregate; however, it is perceived that most deposits would require some form of upgrading for high-specification uses. Potential in situ reserves are estimated to be about 30 000 000 to 35 000 000 t (Thibault 1980; Lavergne and Hunter 1982). This estimate does not take into consideration environmental constraints or potential quality-control problems that may limit or restrict the development of some deposits in certain areas.

Bedrock aggregate resources are particularly extensive in the eastern half of the study area and appear suitable as sources of high-specification material.

METALLIC MINERAL DEPOSITS

Apart from limestone, gypsum, and aggregate resources, areas adjacent to the Plaster Rock Basin have also been explored periodically for metallic mineral deposits. Most occurrences are restricted to Silurian–Devonian and older rock formations in the region.

Precious Metals: Stories of gold strikes are common in the local folklore of the region. One of the most popular tales surrounds the mysterious "Giberson Gold" occurrence. One day in the 1800s, a prospector named George Giberson is said to have returned from a prospecting trip up the Wapske River with a large gold nugget. Understandably, the find sparked considerable excitement throughout the community. Giberson died before he could reveal the location of his hidden bonanza. Some people say that, to this very day, his spirit haunts the bush in the region, pounding on rocks trying to discover the "mother load."

Bedrock-hosted gold occurrences (Plates 92-50A and 92-50B) are also reported in the region (Hind 1865; Wright 1940; St. Peter 1978). Three occur in rocks of the Tobique Group. A few samples from one occurrence returned gold assay values from 0.17 to 0.34 g/t Au. Several samples from the same occurrence contained 0.69 to 2.06 g/t Ag (St. Peter 1978).

Another occurrence has been mentioned that is situated adjacent to the Plaster Rock–Renous Highway approximately 25 km east of Plaster Rock. In 1940, shallow pits were reportedly dug but no details are available (St. Peter 1978).

Base Metals: Several occurrences of copper, lead, zinc, and silver have been reported. Prior to the 1950s, interest in base metal exploration in the Plaster Rock region appears to have been minimal. Since that time, prospectors and several mineral exploration companies have engaged in various geological surveys directed primarily at the region's Devonian volcanic rocks (Plates 92-50A and 92-50B). Over the last two decades, the region has been mapped by government agencies in an attempt to further stimulate exploration activity.

Between 1954 and 1971, geochemical surveys outlined base metal anomalies at Costigan Mountain in felsic volcanic rocks of the Costigan Mountain Formation (Riddell 1971). Between 1970 and 1973, Amoco Canada Petroleum Ltd. carried out extensive geochemical and geophysical surveys to further outline drilling targets. Between 1974 and 1976, Amoco drilled a total of 28 holes to test the anomalous zone (Maingot 1974). In 1979, four more holes were drilled. Lac Minerals Ltd. excavated six trenches and carried out more geological mapping and geophysical (VLF, magnetometer, and IP) surveys in the same year. This was followed by additional diamond drilling. Fyffe and Pronk (1985) have given a detailed account of the bedrock geology, geochemistry, and mineralization of the Costigan Mountain deposit.

According to Lac Minerals Limited (Crevier and Gravel 1985) and Fyffe and Pronk (1985), the mineralization is localized in the core of an east-plunging, funnel-shaped breccia pipe 200 to 350 m in length (see inset sketches on Plate 92-50B). Pyrite, sphalerite, galena, and minor chalcopyrite mineralization occurs as a stockwork of veinlets and disseminations. Lapilli tuff and altered crystal tuff that host the breccia pipe are silicified up to several hundred metres from the

pipe. Fluorite commonly occurs in the mineralized and silicified zones but rapidly decreases in abundance with increasing distance from the pipe.

It has been suggested (Crevier 1984, 1985) that the source of the breccia pipe is a subcropping cupola of the Redstone Mountain Granite, exposed farther to the east. An ore reserve calculation by Lac Minerals Ltd. (Crevier and Gravel 1985) is 6 000 000 to 8 000 000 t grading about 3.25% combined Pb+Zn and 16 g/t Ag.

Most recently, detailed regional mapping and lithogeochemical work conducted by Wilson (1988, 1990) revealed anomalous values of metallic minerals in an outcrop near Sewell Brook, about 20 km northeast of Plaster Rock. The mineralized outcrop is reported to contain 170 ppb Au, 1400 ppm As, 32 ppm Ag, 310 ppm Sb, 1510 ppm Ba, >1000 ppb Hg, 40 ppm W, 85 ppm Tl, 7400 ppm Pb, and 5100 ppm Zn (Wilson 1988). The mineralization is hosted by mainly silicified, sericitized, and chloritized felsic volcanic breccia (hyaloclastic breccia) interbedded with devitrified rhyolites, sedimentary rocks, and minor mafic volcanic rocks (Wilson, personal communication, 1991). This revelation has led to the staking of many mineral claims in the region. The properties for which exploration reports have been received by the Mineral Resources Division are shown on Plate 92-55A. Among interested parties conducting follow-up exploration programmes is NovaGold Resources Inc. Base metal mineralization was intersected in the first hole drilled by NovaGold in the vicinity of the reported anomaly in the autumn of 1990. To date, more than 45 holes have been drilled.

CONCLUSIONS

An inventory and preliminary assessment of mineral resources has been conducted in the vicinity of the village of Plaster Rock, Victoria County, New Brunswick. The area investigated was selected on the basis of what might be considered a reasonable one-way driving distance from the village (i.e., 20-30 km).

Potential rock and mineral resources recognized within the study area include: limestone, gypsum, aggregate (granular and bedrock), and base metals.

Limestone exposures are restricted to the western and southern half of the Plaster Rock Basin, along the Tobique and Wapskehegan rivers. Most are located within a 10 km radius of the village of Plaster Rock.

The limestone is greenish grey to dirty white to reddish brown, very fine grained, and generally nodular. Nodules are often enveloped by red and green shale. Generally lenticular zones of limestone range in thickness from 1 to 20 cm and have a variable lateral extent. Thin interbeds and intercalations of red shale constitute a significant portion of most outcrops.

In general, limestone of the Plaster Rock Basin seldom contains more than 45 to 50% CaO and, failing to satisfy raw material specifications of most limestone-consuming industries, would

be considered substandard. The thickness and lateral extent of high-grade limestone zones are variable.

Until the 1940s, limestone in the Plaster Rock area was used periodically as a local supply of agricultural lime. However, it is probable that the Plaster Rock deposits would not meet quality standards required by todays farming community. Apart from concerns about product quality, stiff competition from established in-province producers would tend to be a hinderance to the establishment of an agricultural lime operation at Plaster Rock. The proximity of the most accessible limestone deposits to habitation, to major watersheds, and to public roads and highways are some of the other obstacles to potential development.

Gypsum deposits at Plaster Rock were once utilized as a soil conditioner (agricultural gypsum). Most operations ceased in the late nineteenth century and no production has been reported since that time.

In general, the quality and extent of the gypsum resource is variable. Gypsum occurs as nodules and thin to massive zones and is often intermixed with abundant amounts of shale.

Gypsum varies from white to dirty white to reddish white in colour. Zones of gypsiferous material vary from a few centimetres to about 1 m in thickness. Variations depend on the lenticular nature and lateral extent of these zones. For the most part, gypsum is disseminated in a shaly to muddy matrix and forms coalescing nodules with thin intervening films or layers of shale. Locally occurring beds of more massive gypsum are seldom more than a few metres thick and their lateral extent is expected to be limited.

With few exceptions, the gypsiferous deposits of Plaster Rock fail to meet basic raw material requirements for most popular gypsum applications (e.g., wallboard manufacture). The resource may offer some potential for agriculture if identified deposits can be reasonably upgraded to appropriate standards or higher-quality deposits can be located. Consumption of agricultural gypsum has shown signs of increasing, particularly in the large potato-producing region of northwestern New Brunswick and northern Maine. The size of this particular ag-gypsum market is not known acurately. However, it is estimated that annual consumption for potatoes alone probably would not exceed 40 000 t of gypsum under even the most favourable conditions. It should be recognized that natural gypsum used for agricultural purposes could eventually face strong competition from byproduct sources from northern New Brunswick.

Aggregate The Plaster Rock area appears to have an adequate supply of aggregate materials and a deficiency in high-quality pit-run granular materials. In order to be used as high-specification granular aggregate, the material would probably have to be washed and screened. The potential for high-specification bedrock aggregate resources in the region is good, particularly in the eastern half of the study area. However, utilization of these resources is transportation sensitive and relies heavily on the demand created by major construction projects. The most economical and consistent supply of specified material is a critical factor in the costing of such projects. Given the remoteness of the Plaster Rock resource from major aggregate-consuming activities (e.g., upgrading the Trans-Canada Highway), production in the region would most likely

be sporadic and short-lived. As a consequence, developments of this nature would probably have a short-term impact ("boom-bust cycle") on the region's economy.

Base Metals occurrences in the Plaster Rock region are restricted to rocks of Lower Devonian age. They appear to have the potential for hosting volcanogenic massive sulphide or epithermal mineral deposits. The discoveries at Costigan Mountain in the 1970s and at Sewell Brook in the 1990s may continue to act as the catalyst for future exploration activity and eventual mineral development in the region.

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APPENDIX A. RESULTS OF ENGINEERING TESTS

ON SELECTED BEDROCK AGGREGATE SAMPLES

FROM THE AREAS ADJACENT TO THE PLASTER ROCK BASIN

Note: These samples were collected by the authors in 1990; sample preparation and engineering tests were carried out in the Division's Mineral Processing Laboratory by M. O'Donnell. Sample locations have been plotted on Plates 92-51A and 92-51B (in pocket).

Appendix A. Results of Engineering Tests on Selected Bedrock Aggregate Samples from the Areas Adjacent to the Plaster Rock Basin

NTS Map	Sample	Rock Type	Mechanical Analysis			Sodium Sulphate Soundness (loss in %)	Absorption (%)	Los Angeles Abrasion (loss in %)
			Gravel % >4.75 mm	Sand % 4.75 mm to 75µm	Silt % <75 µm			
21 J/14	BR/82/90	Grey to purple felsic porphyry	83.3	15.9	0.8	0.21	0.60	9.3
21 J/14	BR/83/90	Pinkish grey felsic porphyry	83.1	15.6	1.3	0.54	1.11	12.3
21 J/14	BR/84/90	Greyish green, medium to coarse gabbro	79.4	18.7	1.9	0.59	0.66	9.8
21 J/14	BR/85/90	Greyish green, vesicular to amygdaloidal basalt	81.4	16.8	1.8	0.37	0.85	9.3
21 J/14	BR/86/90	Greyish green meta-sediment	81.0	17.1	1.9	0.05	0.93	8.0
21 J/14	BR/87/90	Grey hornfelsic sandstone	83.3	15.4	1.3	1.32	0.90	12.1
21 J/14	BR/88/90	Pink felsic volcanic rock	80.7	17.1	2.2	1.26	1.46	13.9
21 J/14	BR/89/90	Grey to greyish purple basalt	84.1	14.6	1.3	0.96	1.45	8.9
21 J/14	BR/90/90	Greyish green basalt	81.1	16.8	2.2	1.83	0.86	10.6
21 J/14	BR/91/90	Pinkish grey gabbro	83.4	15.1	1.5	1.21	1.15	12.1
21 J/14	BR/92/90	Dark grey quartz wacke	82.7	15.4	1.9	1.72	1.01	11.7
21 J/14	BR/93/90	Greyish green gabbro	80.9	17.1	2.0	0.10	0.59	9.8
21 J/14	BR/94/90	Dark grey quartz wacke	82.0	16.4	1.6	0.86	0.47	10.8
21 J/14	BR/95/90	Greyish green gabbro	84.2	14.5	1.3	10.83	0.90	13.2
21 O/3	BR/96/90	Pink felsic volcanic rock	79.3	19.0	1.7	2.78	1.61	13.1
21 O/3	BR/97/90	Dark green lithic wacke	82.7	15.6	1.7	1.71	1.31	11.2
21 J/14	BR/99/90	Greyish green mafic volcanic rock	83.7	14.8	1.5	1.08	0.78	9.8
21 J/14	BR/100/90	Greyish green mafic volcanic rock	83.3	15.6	1.1	0.97	1.14	10.7
21 J/14	BR/101/90	Greyish pink felsic porphyry	82.7	16.0	1.3	1.34	1.35	12.0
21 J/14	BR/102/90	Greyish green mafic volcanic rock	76.1	21.2	2.7	9.20	0.97	14.1
21 J/14	BR/103/90	Greyish pink prophyritic felsic volcanic rock	82.4	16.8	0.8	0.49	0.92	10.2
21 J/14	BR/104/90	Greyish pink porphyritic felsic volcanic rock	82.8	16.0	1.2	1.07	0.87	10.0

Appendix A (concluded)

NTS Map	Sample	Rock Type	Mechanical Analysis			Sodium Sulphate Soundness (loss in %)	Absorption (%)	Los Angeles Abrasion (loss in %)
			Gravel % >4.75 mm	Sand % 4.75 mm to 75µm	Silt % <75 µm			
21 J/14	BR/105/90	Greyish green basalt	79.6	17.6	2.8	0.87	2.09	14.8
21 J/14	BR/106/90	Pink and purple felsic volcanic rock	84.4	14.2	1.4	0.66	1.09	10.8
21 J/14	BR/107/90	Purple volcanic tuff breccia	84.9	14.4	0.7	0.51	0.81	10.1
21 J/14	BR/109/90	Greyish green diabasic gabbro	81.2	17.2	1.6	0.64	0.87	12.2
21 J/13	BR/110/90	Pink felsic volcanic rock	81.6	16.8	1.6	0.28	1.54	12.6
21 J/14	BR/111/90	Pink to reddish pink felsic volcanic rock	85.4	14.1	0.5	3.00	1.09	12.6
21 J/14	BR/112/90	Greyish green diabasic gabbro	84.7	13.8	1.5	0.88	1.13	12.1
21 J/14	BR/108/90	Dark greyish purple felsic volcanic rock	82.5	16.9	0.6	0.44	0.53	12.3
21 J/14	BR/116/90	Pink felsic volcanic rock	80.8	17.9	1.3	2.12	1.27	14.4
21 J/14	BR/115/90	Pink felsic volcanic rock	83.5	15.2	1.3	0.29	0.66	9.6
21 J/14	BR/124/90	Purple to maroon sandstone	80.9	16.6	2.5	0.39	1.70	13.4
21 J/14	BR/125/90	Greyish green to green gabbro	80.7	17.2	2.1	0.09	0.67	9.9
21 J/14	BR/133/90	Grey to purplish grey micaceous sandstone	80.4	18.7	1.9	4.24	1.44	11.2
21 J/14	BR/134/90	Greyish green diabase	80.4	17.4	1.8	3.48	1.13	11.0
21 J/14	BR/135/90	Dark green gabbro diabase	78.2	19.0	2.8	3.78	1.04	11.6
21 J/13	BR/117/90	Pink felsic volcanic rock	78.3	19.5	2.2	1.42	1.73	13.4
21 J/13	BR/118/90	Greyish green mafic volcanic rock	82.6	16.0	1.4	0.14	1.21	10.1
21 J/13	BR/119/90	Greyish green mafic volcanic rock	80.9	17.1	2.0	0.48	0.62	10.3
21 J/13	BR/120/90	Greyish green mafic volcanic rock	82.2	16.5	1.3	2.18	1.25	9.3
21 J/13	BR/121/90	Reddish pink felsic volcanic rock	82.1	17.3	0.6	0.87	1.28	11.7
21 J/13	BR/122/90	Reddish pink felsic volcanic rock	82.2	16.7	1.1	1.03	1.75	10.9
21 J/13	BR/123/90	Greyish green mafic volcanic rock	80.3	17.5	2.2	0.77	1.12	10.3

MAPS
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